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Estimating greenhouse gas emissions in Louisiana at the parish scale

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ESTIMATING GREENHOUSE GAS EMISSIONS IN LOUISIANA AT THE PARISH SCALE

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LIST OF ABBREVIATIONS

Abbreviation	Term
CACP	Clean Air & Climate Protection
CES	LSU Center for Energy Studies
DVRPC	Delaware Valley Regional Planning Commission
EIA	Energy Information Administration
EIIP	Emission Inventory Improvement Program
EPA	Environmental Protection Agency
GHG	Greenhouse Gas
GWP	Global Warming Potential
IPCC	Intergovernmental Panel on Climate Change
ICLEI	Local Governments for Sustainability
LED	Louisiana Economic Development
LGOP	Local Government Operations Protocol
LPG	Liquefied Petroleum Gas
LULUCF	Land Use, Land-Use Change and Forestry
MPO	Metropolitan Planning Organization
NJTPA	New Jersey Transportation Planning Authority
ODS	Ozone-Depleting Substances
SIT	State Inventory Tool
UNFCCC	United Nations Framework Convention on Climate Change
WashCOG	Washington Council of Governments

ABSTRACT

The estimation of greenhouse gas (GHG) emissions and removals from the atmosphere at the county scale is an interest to many local decision makers and scientists looking to plan, track, mitigate, or reduce concentrations at the local or regional level. This thesis presents a new approach in downscaling state-level emissions to contiguous county levels using the state of Louisiana as an example. Here, we applied the volume-preserving principle in an attempt to improve existing methods and fully characterize accurate GHG emissions at the county (i.e., parish) level. All six "Kyoto" GHG emissions related to sources and sectors were assessed and consistent with prevailing national standards. The results, completed for the year 2005, addressed an accuracy issue by accounting for 97.74% of the state's gross emissions, whereas previous existing methods were only able to account for approximately 79% of the total to Louisiana's 64 parishes. A comparison of the volume-preserved results with a generally higher resolution bottom-up inventory for the City of New Orleans/Orleans Parish revealed consistent estimates across most sectors.

CHAPTER 1: INTRODUCTION

In the past few decades, the global climate system has experienced increased warming, evident from higher measurements of average air and ocean temperatures, reports of snow and ice melts, and global sea level rise. Findings in the IPCC Fourth Assessment Report conclude that concentrations of greenhouse gases (GHG) in the atmosphere are increasing as a direct result of human activities such as the burning of fossil fuels in transportation or electricity production (IPCC 2007). These record-high increases in anthropogenic GHGs are therefore believed to be influencing climate change.

In response to the effects of climate change, world leaders have determined that it is critical to reduce GHG emissions in order to stabilize the concentration in the atmosphere. In order to manage and reduce or stabilize GHG concentrations, we must measure their emissions. This has led to the development of GHG inventories, defined as an "accounting of greenhouse gases emitted to or removed from the atmosphere over a period of time" (EPA 2011). Scientists use inventories to improve atmospheric and climate models; policy makers use them to develop strategies in emissions reductions and to track the progress of those strategies and policies; and regulatory agencies and corporations use them to assess compliance of emission rates.

To date, there have been many GHG inventory efforts at different scales. At the national level, the United States Environmental Protection Agency (EPA) accounted for all six "Kyoto GHG" emissions in several sectors for the United States in the annual "Inventory of U.S. Greenhouse Gas Emissions and Sinks" report (EPA 2011a) using well-established methodologies defined in the Revised 1996 IPCC Guidelines for

National Greenhouse Gas Inventories released by the Intergovernmental Panel on Climate Change (IPCC/UNEP/OECD/IEA 1997). Participating states, including Louisiana in a report prepared by Louisiana State University's Center for Energy Studies (LED 2010), have submitted their GHG inventory reports to the EPA using guidelines and tools developed by the EPA called the State Inventory Tool (SIT). At the local level, participating cities and large municipalities, including Orleans Parish (City of New Orleans 2009), developed their GHG inventories using guidelines in the Local Government Operations Protocol (LGOP) provided primarily by Local Government for Sustainability (ICLEI 2008). In 2009, ICLEI released CACP (Clean Air & Climate Protection) version 3.0, a software product that incorporated the LGOP standard guidelines to assist local governments in developing GHG inventories easier.

The inventories described above use methods that have become standards and widely accepted in the climate science field. There is, however, a need for GHG quantification at less coarse scales. There are no established or standardized guidelines for regional or contiguous county-level GHG emission estimations for inventory purposes. Recently, there have been attempts by metropolitan planning organizations (MPO) to produce a regional GHG inventory that includes allocated estimates for all contiguous counties inside of a region. These MPOs are the Delaware Valley Regional Planning Commission (DVRPC), New Jersey Transportation Planning Authority (NJTPA), and Metropolitan Washington Council of Governments (WashCOG). Each inventory was developed in collaboration as pilot projects with the EPA, and as a result, the EPA is currently in development with a draft of a regional GHG inventory guidance (EPA 2011b).

The results of the methods introduced by these pilot project participants have generally estimated acceptable regional GHG emissions at their respective geographic regions. However, an issue with accuracy, reported in DVRPC's Regional Greenhouse Gas Emissions Inventory (DVRPC 2010), in the methods developed to allocate emissions from region to county levels only accounted approximately ninety percent (90%) of the gross emissions. Also of note is that these studies were done in the same general northeast region of the United States, and not tested in other parts of the country where variations in activity are to be expected. Theoretically, one can use local scale bottom-up approaches to estimate multiple county-level estimates for contiguous counties to achieve higher accuracy. However, many counties have limited resources, such as data availability and capacity, to employ the rigorous methods demanded by the ICLEI guidelines, as noted in the inventorying process documented in New York City's GHG report (City of New York 2009). Additionally, bottom-up approaches tend to over-estimate or under-estimate and do not guarantee volume preserving (Shu et al. 2010, Lam 1983, Tobler 1979). Therefore, it is necessary to develop a simple and accurate method to address these issues.

This study examines the state of Louisiana and its parishes (counties) as an example to demonstrate the application of a proposed volume-preserving method in downscaling the estimation of greenhouse gases from state to county level. Currently, the only county-level GHG inventory in the state of Louisiana exists for Orleans parish (City of New Orleans 2009), and the state-level inventory is not annually updated to include revisions that incorporate the latest methodological improvements, such as emission factors and the electricity consumption module based on new guidance from EPA (ICF

International 2011). The research objective of this study is to estimate county-level GHG emissions by addressing spatial resolution, accuracy, and relationships in source emissions by: (1) applying existing quantification methods for the state of Louisiana to obtain an accurate baseline data incorporating EPA's new guidance materials, (2) applying existing allocation methods developed by the DVRPC to obtain Louisiana parish-level estimates, (3) further optimizing allocation and downscaling methods utilizing a proposed top-down approach with the volume-preserving principle and assumptions to characterize accurate GHG emissions at the parish level to the extent practicable, and (4) evaluating the results of existing and proposed methods by comparing GHG emission estimates for the state and parishes.

CHAPTER 2: BACKGROUND

In 1996, leading scientists and experts from over thirty countries collaborated under Working Group 1 of the Intergovernmental Panel on Climate Change (IPCC) to develop the 1996 IPPC Guidelines for National Greenhouse Gas Inventories to assist developing nations in inventorying greenhouse gas (GHG) emissions. The development of these guidelines was crucial in assessing the science behind human-induced climate change and its impacts. A year later, the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC/UNEP/OECD/IEA 1997) was released to ensure that emission inventories were consistent and comparable between nations who have signed and ratified the United Nations Framework Convention on Climate Change (UNFCCC). Provisions in the UNFCCC Convention require that parties develop, periodically update, and publish national GHG inventories of anthropogenic emissions using comparable methodologies. In addition to the provisions in the UNFCCC, the Kyoto Protocol was introduced to identify key greenhouse gases (CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6) that affect global average atmospheric concentrations over long timeframes (IPCC/UNEP/OECD/IEA 1997). In 2006, as new scientific and technical knowledge improved, the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006) was released that included improvements in methodologies as well as new sources and gases. The latest IPCC guidelines provided the scientific basis for the eventual development of many other standardized guidelines by groups of climate scientists and experts who wished to track GHG emissions at smaller scales. The following section generally describes the existing emissions inventory guidelines that have been developed in the United States to support the stabilization of anthropogenic GHG emissions in the atmosphere at scales ranging from national to local levels.

2.1 Existing GHG Emissions Inventory Guidelines in the U.S.

Since 1998, the United States Environmental Protection Agency (EPA) have been developing and publishing periodical greenhouse gas inventories to track national trends in emissions and removals for the United States (EPA 2011a). Under the commitment to the UNFCCC, these inventories have been submitted to the United Nations on an annual basis. Anthropogenic GHG emissions from various source and sink categories have been estimated using methods that are consistent with the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC/UNEP/OECD/IEA 1997), the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC 2000), the IPCC Good Practice Guidance for Land Use, Land-Use Change, and Forestry (IPCC 2003), and the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006). Generally, the methods follow a top-down reference approach relying on aggregated activity data with emission factors that relate how much is emitted per unit activity. In order to simplify the reporting of estimates, the IPCC (2001) developed the Global Warming Potential (GWP) concept to compare the ability of each greenhouse gas to trap heat in the atmosphere relative to CO_2, therefore its unit is million metric tons of carbon dioxide equivalent ($MMTCO_2E$). Emissions estimates are broken down into individual sources of activity for each major sector (Energy; Industrial Processes; Solvent and Other Product Use; Agriculture; Land Use, Land-Use Change, and Forestry [LULUCF]; and Waste). Recently, recalculations have been made to the

U.S. greenhouse gas emission estimates either to incorporate new methodologies or to update recent historical data.

In 1998, the EPA developed the State Inventory Tool (SIT) under the Emission Inventory Improvement Program (EIIP) to assist interested states in developing their own GHG inventories to track state-level emissions and develop state climate action plans (EPA 2011b). The SIT leverages on the computational power of Microsoft's Excel software to estimate all six "Kyoto" GHGs for most sources and sectors in an easy-to-use format that increases accuracy and consistency across states. The estimates are calculated in separate modules based on methods that are consistent with national guidelines. For each module, aggregated data are input using state-supplied or default data, and the calculation (top-down approach) takes state-specific emission factors into account for each source activity. The output estimates are then synthesized using a final interactive spreadsheet to produce a summary table of all GHG emissions in $MMTCO_2E$ according to sectors. In early 2011, the EPA released a new version of the SIT that included the Electricity Consumption module and updated emission factors (ICF International 2011). The rationale behind developing the new module is to estimate indirect emissions and quantify how much electrical energy a state consumes, which helps states plan potential mitigation options. The new module estimates emissions of various equipment types based on state electricity consumption data from the Energy Information Administration's State Energy Data System for the residential, commercial, industrial, and transportation sectors. Since the release of the SIT's 2011 version, many states have incorporated the new methods and emission factors to create or update their state-level emissions (MDE 2011, Washington State 2010).

Some metropolitan regions are now also developing GHG inventories, a relatively new concept that estimates the total region and all contiguous counties within. This is generally done by estimating emissions at the regional scale based on methods provided in the EPA's SIT. Emissions for each source and sector are then allocated to counties by using a hybrid of top-down and bottom-up approaches. As a pilot project with the EPA, the Delaware Regional Planning Commission (DVRPC) released its Regional Greenhouse Gas Emissions Inventory for the nine-county Greater Philadelphia region in March 2009, later revised in December 2010 to account for updated emission factors (DVRPC 2010). The study includes a report of their 2005 emissions at the regional and county level, along with methods and guidelines consistent with state and national standards. The allocation method to produce county-level estimates is a blend of top-down and bottom-up approaches; this was decided based on data availability, existing protocols, and resource limitations. Overall, the results show that the county allocation method was able to allocate approximately 90% of the 2005 regional estimates to the nine counties of Greater Philadelphia.

2.2 Top-Down Versus Bottom-Up Approaches

Usually, there are two approaches in developing greenhouse gas inventories: top-down and bottom-up. Top-down estimates depend on data that are collected and aggregated by state and national agencies. The bottom-up approach takes the opposite perspective by deriving estimates from data collected at the source, and then aggregated to the higher level. There have been many debates on which approach produces more reliable GHG estimation results in the literature (Ciais et al. 2010, Rivier et al. 2010, Gusti and Jonas 2010); however, the consensus usually agrees that it depends on the goals and capacity. The main weakness of the top-down approach have been documented as having uncertainties from the assumptions (Marland 2008), but the advantages of its ability to leverage existing data and process the data in standardized protocols and principles consistently in a timely manner influenced the methodology choice and basis for this thesis. Because one of the objectives is to account for all emissions within the state at the parish level, the top-down approach, along with the volume-preserving principle (Shu et al. 2010, Lam 1983, Tobler 1979), guarantees that the analysis includes close to everything. This does not discount the value of a bottom-up approach, as estimates from this approach may not only be used to achieve better insight into emissions, but also help identify errors and validate results from a consistency point of view (Jonas et al. 2010). This thesis also attempts to apply this double-entry bookkeeping in a limited scale to find out if the sums balance.

CHAPTER 3: STUDY AREA AND DATA

3.1 Louisiana

The focus of this study is the state of Louisiana, including all sixty-four (64) parishes (Figure 1). The state of Louisiana is chosen for its unique energy-producing characteristic in comparison to the other states in regions presented in previous studies. The following list describes the state's energy profile: Louisiana ranks fourth among the states in crude oil production, behind Texas, Alaska, and California; Louisiana's total and per capita energy consumption rank among the highest in the nation; two of the U.S. Strategic Petroleum Reserve's four storage facilities are located in Louisiana; Louisiana's per capita residential electricity consumption is high, due in part to high demand for air-conditioning during the hot summer months and the widespread use of electricity as the primary energy source for home heating; and Louisiana is one of the top natural gas-producing and consuming states in the country (EIA 2011a). These may potentially reveal discrepancies or inconsistencies in the results based on the methodologies used. Further, the state is also highly vulnerable to the effects of climate change, sea-level rise, and rapid subsidence (Figure 2).

The year 2005 was selected as the baseline year because it is consistent with U.S. climate legislation demands and data availability. "In response to the FY2008 Consolidated Appropriations Act (H.R. 2764; Public Law 110–161), EPA issued the Mandatory Reporting of Greenhouse Gases Rule (74 FR 56260) which requires reporting of greenhouse gas (GHG) data and other relevant information from large sources and suppliers in the United States” (EPA, 2011c); the deadline to submit 2010 reports has been set for September 30, 2011.

Figure 1: Reference Map of Louisiana and Parishes

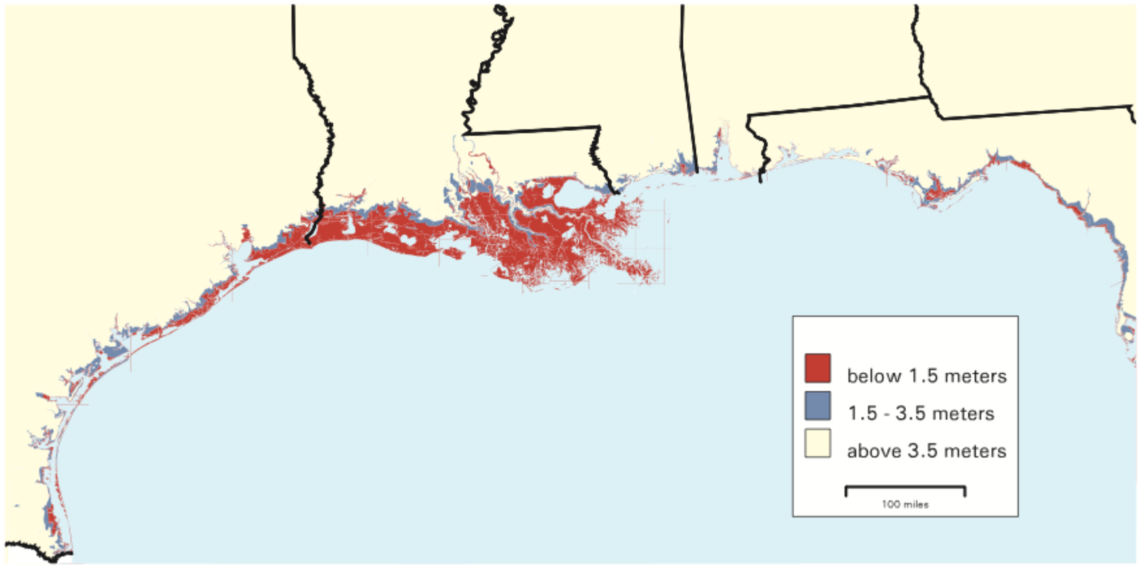

Figure 2: Vulnerability to Sea Level Rise (Titus et al. 2008)

3.2 Data

To obtain state-level baseline GHG emission estimates, state-level activity data in each sector and subcategory along with the corresponding emission factors are required (Table 1). Default and non-default data in the EPA's SIT are used and also identified in Table 1. To obtain parish-level allocated GHG emission estimates using the DVRPC and volume-preserving methods, various bottom-up and top-down activity and proxy data (for purposes of defining allocation factors or indicators with proportional correlative assumptions) for all sixty-four parishes are required and listed in Table 2.

Table 1: State-Level Activity Data and Sources According to Sector

Sector	Activity Data	Source	Default Data
All Stationary	CO_2 from fossil fuel combustion	State Energy Data System (EIA 2011b)	☑
All Stationary	CH_4 and N_2O from Stationary Combustion	State Energy Data System (EIA 2011b)	☑
All Stationary	Emission and transmission loss factors	EPAeGRID2010 V. 1.1, year 2005 (EPA 2010)	☑
All Stationary	State-level electricity consumption data	State Energy Data System (EIA 2011b)	☑
Residential	Residential other fuels consumption	Residential Sub-sectors: State Energy Data System (EIA 2011b)	☑
Commercial	Commercial other fuels consumption	Commercial Sub-sectors: State Energy Data System (EIA 2011b)	☑
Industrial	Industrial other fuels consumption	Industrial Sub-sectors: State Energy Data System (EIA 2011b)	☑
Mobile	Highway Vehicles	Highway Statistics (FHWA 2010)	☑
Mobile	Non-road fuel sales	Highway Statistics (FHWA 2010)	☑
Mobile	Aviation gas sales	Fuel Cost and Consumption (DOT 2009)	☑
Agriculture	Livestock population	NASS (USDA 2010)	☐
Agriculture	Crop production	NASS (USDA 2010)	☑
Agriculture	Fertilizer use	NASS (USDA 2010)	☑
Waste	Waste in place in the state	Solid Waste Facilities (EPA 1988)	☑
Waste	Quantity of landfill CH_4 recovered or flared	Landfill Methane and Outreach Program (EPA 2009)	☑
Waste	GHG Emissions from Waste Combustion	Anthropogenic Methane Emissions (EPA 1993)	☑
Waste	N_2O from Municipal Wastewater Treatment	Table 8-13 (EPA 2011a)	☑
Waste	CH_4 from Industrial Wastewater Treatment	EPA (2011a)	☑
I.P.	Cement production	Cement: Annual Report (USGS 2011)	☑
I.P.	Lime manufacture	Minerals Yearbook: Lime (USGS 2005)	☑
I.P.	Limestone and dolomite use	Crushed Stone Report (USGS 2010b)	☑
I.P.	Soda ash manufacture and consumption	Soda Ash (USGS 2010a)	☑
I.P.	Nitric acid production	Chemical Economic Handbook (TIG 2002a)	☐

(table continued)

I.P.	Adipic acid production	Chemical Market Reporter (CMR 2001)	☑
I.P.	Aluminum production	Aluminum Annual Report (USGS 2007)	☑
I.P.	HCFC-22 production	Mesyanzhinov (2000)	☐
I.P.	Semiconductor manufacture	EPA (2011a)	☑
I.P.	Electric power transmission and distribution	Electric Power Annual (EIA 2010a)	☑
I.P.	Magnesium production and processing	USGS (2010c)	☑
I.P.	Ammonia production and Urea consumption	TIG (2002b)	☑
I.P.	Iron and steel production	DOE (2000)	☐
F.E.	Number of natural gas wells	Gas Facts (AGA 1998)	☑
F.E.	Number of off-shore platforms in the Gulf of Mexico	CES (2010)	☐
F.E.	Number of off-shore platforms not including those in the Gulf of Mexico	Offshore Information (BOEMRE 2010)	☑
F.E.	Miles of gathering pipeline	Pipeline Annual Mileage (OPS 2010)	☐
F.E.	Number of gas processing plants	Worldwide Gas Processing (OGJ 2010)	☐
F.E.	Number of gas transmission compressor stations	LA DEQ, 2007 Certified Emissions (CES 2010); EIA (2009)	☐
F.E.	Number of gas storage compressor stations	LA DEQ, 2007 Certified Emissions (CES 2010); EIA (2009)	☐
F.E.	Miles of transmission pipeline	Pipeline Annual Mileage (OPS 2010)	☐
F.E.	Number of LNG storage compressor stations	LA DEQ, 2007 Certified Emissions (CES 2010); EIA (2009)	☐
F.E.	Miles of cast iron distribution pipeline	DOT (2010)	☐
F.E.	Miles of unprotected steel distribution pipeline	DOT (2010)	☐
F.E.	Miles of protected steel distribution pipeline	DOT (2010)	☐
F.E.	Miles of plastic distribution pipeline	DOT (2010)	☐
F.E.	Total number of services	DOT (2010)	☐

(table continued)

F.E.	Number of unprotected steel services	DOT (2010)	☐
F.E.	Number of protected steel services	DOT (2010)	☐
F.E.	Natural Gas Vented and Flared	EIA (2010b) Natural Gas Navigator	☑
F.E.	Oil Production	Table 14 (EIA 2010c)	☑
F.E.	Oil Refined	Petroleum Supply Annual (EIA 2010c)	☐
F.E.	Oil Transported	Petroleum Supply Annual (EIA 2010c)	☐
LULUCF	Urea Fertilization	AAPFCO (2010)	☑
LULUCF	Liming of Agricultural Soils	Agricultural Chemistry Program, LA Departm ent of Agriculture (CES 2010)	☐
LULUCF	Settlement Soils	AAPFCO (2010)	☑
LULUCF	Urban Trees	U.S. Census, 1990 and 2000; Nowak, et al. (2001)	☑
LULUCF	Forest Fires	LA Department of Agriculture and Forestry, Ten Year Fire Data (CES 2010)	☐
LULUCF	Landfilled Yard Trimmings and Food Scraps	(EPA 2009)	☑

I.P. = Industrial Processes.
F.E. = Fugitive Emissions
LULUCF=Land Use, Land-Use Change, and Forestry.

Table 2: Indicator Data for Downscaling State Associations to Parish Level

Sector	Indicator	Source	Method
Residential	Population	U.S. Census Bureau (2005)	DVRPC, VP
Residential	Number of households	U.S. Census Bureau (2009)	DVRPC
Residential	Number of households that use specific fuels	U.S. Census Bureau (2009)	VP
Commercial	Number of households	U.S. Census Bureau (2009)	DVRPC, VP
Commercial	Population	U.S. Census Bureau (2005)	VP
Commercial	Employment counts	U.S. Bureau of Labor Statistics (2005)	DVRPC, VP
Industrial	Employment counts	U.S. Bureau of Labor Statistics (2005)	DVRPC
Industrial	Employment in NAICS 21 and 31-33	U.S. Census Bureau (2009)	VP
Mobile	Workers commuting by public transit	U.S. Census Bureau (2009)	DVRPC, VP
Mobile	Length of roadway	U.S. Census Bureau (2010)	VP
Mobile	Length of rail tracks	DOT (2006)	VP
Mobile	Length of waterway	Louisiana Oil Spill Coordinator's Office (1999)	VP
Mobile	Airport counts	DOT (2009)	VP
Agriculture	Livestock population	USDA (2010)	DVRPC, VP
Agriculture	Crop production	USDA (2010)	DVRPC, VP
Waste	Population	U.S. Census Bureau (2005)	DVRPC, VP
I.P.	Population	U.S. Census Bureau (2005)	DVRPC, VP
I.P.	Population	U.S. Census Bureau (2005)	DVRPC, VP
I.P.	Number of establishments	U.S. Census Bureau (2002)	VP
LULUCF	Carbon stock factors	Van Deusen et al. (2011)	DVRPC, VP
LULUCF	Forest acreage	USDA (2008)	DVRPC
LULUCF	Forest acreage by species mix	USDA (2008)	VP
LULUCF	Urbanized area	U.S. Census Bureau (2010)	DVRPC, VP
LULUCF	Urban tree coverage	Nowak et al. (2001)	DVRPC, VP

I.P. = Industrial Processes.
LULUCF = Land Use, Land-Use Change, and Forestry.
DVRPC = Delaware Valley Regional Planning Commission method.
VP = Volume-Preserving method.

CHAPTER 4: METHODS

4.1 Estimating State-Level Baseline Data

Even though a Louisiana GHG inventory exists for the year 2005 using a March 2007 version of the State Inventory Tool (CES 2010), the results did not account for electricity consumption (indirect emissions) and updated emission factors. For this study, a new baseline data at the state level that incorporates the new guidelines is developed for the year 2005. The EPA's January 2011 version of the State Inventory Tool (SIT) is used to calculate and account all of the major direct and indirect GHG emissions for each sector and its subcategories for the state of Louisiana in units of million metric tons of CO_2 equivalent ($MMTCO_2E$) - a sum which includes the quantity of each GHG weighted by a factor of its effectiveness as a GHG, using CO_2 as a reference (Table 3). The SIT is divided into modules based on the source of emissions inventoried, as shown in Table 4. These eleven modules have self-contained equations and models, and can import default or non-default data and output emissions estimates in converted $MMTCO_2E$ based on the latest emission factors. The general calculation methods used and the sectors covered are the same as those in the U.S. GHG Inventory (EPA2011a).

Table 3: Global Warming Potential (GWP)

Gas	Formula	GWP
Carbon dioxide	CO_2	1
Methane	CH_4	21
Nitrous oxide	N_2O	310
Hydroflourocarbon-23	HFC-23	11,700
Perflourocarbons	PFCs	Varies
Tetraflouromethane	CF_4	6,500
Hexaflorомethane	C_2F_6	9,200
Sulfurhexaflouride	SF_6	23,900

Source: U.S. EPA (2011a)

Table 4: SIT Modules and Emission Sources

Module	Emission Sources	GHGs
Agriculture	Enteric fermentation, Manure mgmt., Agriculture soils	CH_4, N_2O
CO_2 Fossil Fuel Combustion	Fuel use by sector	CO_2
Coal Mining	Underground and surface mines	CH_4
Electricity Consumption	Indirect emissions by sector	CO_2, N_2O, CH_4
Industrial Processes	Cement, Lime, Soda ash, Iron and steel, Ammonia, Nitric acid, Adipic acid, Aluminum, HCFC-22, ODS	CO_2, N_2O, HFC, PFC, SF_6
LULUCF	Urban trees, Settlement soils, Forest fires	CO_2, CH_4, N2O
Mobile	Highway, Aviation, Marine, Locomotives, Non-road	CH_4, N_2O
Natural Gas and Oil	Production, Refining (oil), Transmission, Distribution, Venting and flaring (natural gas)	CO_2, CH_4
Solid Waste	Landfills, Waste combustion	CH_4
Stationary Combustion	Fuel use by sector	CH_4, N_2O
Wastewater	Municipal, Industrial	CH_4, N_2O

Source: ICF International (2011)

The newest version of the SIT (released January 2011) introduces the Electricity Consumption module and updated emission factors for more accurate estimations. The Electricity Consumption module was developed to estimate indirect emissions from electricity consumption at the state level. Direct emissions (estimated in the separate CO_2 from Fossil Fuel Combustion module) are estimated from the combustion of fossil fuels at the point of electricity generation, while indirect emissions are estimated based on electricity usage (ICF International 2011). This inclusion is consistent with the regional inventory method developed by DVRPC. It is, therefore, essential to use the 2011 version of the SIT, of which state scale estimates in this study are comparable to regional scale estimates. The default and non-default data used in the original Louisiana GHG inventory report are restored in this study to enable data input consistency (Table 1).

Greenhouse gas emissions are estimated for energy used in the residential, commercial, and industrial sectors, as well as in the transportation sector, including on-road transportation, passenger and freight rail, aviation, marine transportation, and off-road vehicles. Non-energy-related emissions resulting from waste management (solid waste and wastewater), agriculture processes (both animal and plant related), industrial processes, and fugitive emissions from fuel systems (natural gas systems and petroleum systems) are also included. CO_2 removed from the gross total are measured by accounting for land use, land use change, and forestry processes.

4.2 Downscaling from State to Parishes

4.2.1 DVRPC Method

The first method used to downscale to parish-level GHG emission estimates is the Delaware Valley Regional Planning Commission's (DVRPC) allocation method. The report (DVRPC 2010) contains a section detailing how to allocate regional estimates to the county scale using a hybrid of top-down and bottom-up approaches for each sector and subcategory. An important note concerning this method involves the intentional omission of sources due to limited resources (i.e., data and time) and a decision to direct its resources toward quantifying the largest sources of emissions based on local regional and sub-regional policies suited to help reduce GHG concentrations. County allocation excludes the following sources that are included in the regional total: industrial fuels other than coal, distillate, kerosene, and liquefied petroleum gas (LPG); highway through-traffic and airport traffic; freight rail; intercity rail; aviation; marine and port related sources; cement and iron/steel production; and fugitive emissions from petroleum systems. As Table 5 indicates, DVRPC believes that over 90 percent of the allocated emissions are allocated using the same methodology as would be used to carry out an inventory for another region or counties.

Table 5: 2005 DVRPC Regional and County GHG Emissions Inventory

Emissions Sector Category	**Region Total ($MMTCO_2E$)**	**County Total ($MMTCO_2E$)**
Residential Energy	21.14	21.06
Commercial Energy	15.74	15.34
Industrial Energy	16.34	13.33
Mobile Energy	27.23	21.82
Agriculture	0.45	0.45
Waste	1.88	1.88
Wastewater	0.69	0.69
Industrial Processes	1.97	1.97
Fugitive	0.78	0.64
LULUCF	0.15	0.15
Net Total	**86.36**	**77.32**

Source: DVRPC (2010)

4.2.2 Volume-Preserving Method

The second method applies the volume-preserving principle to downscale state emissions to the extent practicable down to the parish level. In general, emissions were calculated 'top-down' (based on national or state data) and allocated geographically based on other variables and indicators (assumptions) to maintain relative proportionality of emission estimates. Examples of indicators that can be used to downscale state-level estimates (e.g., energy consumption) to the parish level are the number of households, population, measures of industrial production, and employment (see Table 2 for the full list of indicators). The assumptions of the indicators are based on literature review of guidelines, including all scales and bottom-up/top-down approaches, and published articles on correlative studies in the climate change and emissions field. Shu et al. (2001) presents the general equation (1) for enforcing the volume-preserving property as:

$$u_s = e_s / t_s \qquad \text{(Eq. 1)}$$

where the emission value (e_s) at state s is divided by the total weights of all parishes within the state (t_s) to find the unit emission value within the state (u_s), respective of emission source activity. Equation 2 then determines the emission value for each parish (e_p) by multiplying the unit emission value and weight:

$$e_p = w_p \times u_s \qquad \text{(Eq. 2)}$$

Once downscaling is performed, activity data per parish can be summed across all sixty-four parishes to conform to the state baseline estimate. An overview of the volume-preserving equations used to prepare county-level estimates for each sector is presented below.

4.2.2.1 Stationary Energy Consumption

In the residential sector, direct emissions are the result of burning coal, distillate fuel, kerosene, liquefied petroleum gas (LPG), and natural gas. Equation 3 assumes that the number of households in a parish using a particular fuel directly affects the amount of emissions in the parish for each fuel. Population data is used to downscale electricity

$$\left(\frac{\#\,households\ fuel\ use\,(parish)}{\#\,households\ fuel\ use\,(state)}\right) \times fuel\ emissions\,(state) \qquad \text{(Eq.3)}$$

consumption in the residential sector. Equation 4 assumes that each parish's population is uniformly distributed, and that all consumers in a parish consume electricity equally.

$$\left(\frac{population\,(parish)}{population\,(state)}\right) \times electricity\ consumption\,(state) \qquad \text{(Eq.4)}$$

The commercial sector includes emissions from the following fuels: coal, distillate fuel, kerosene, LPG, residual fuel, motor gasoline, and natural gas. To distribute these commercial fuel usages and emissions to the parish level, employment counts per parish serve as the basis. Equation 5 assumes that these fuels in the commercial sector correlate with employment. For commercial electricity consumption, the same method is

$$\left(\frac{employment(parish)}{employment(state)}\right) \times fuel\,emissions(state) \qquad \text{(Eq. 5)}$$

used as in Equation 4, which assumes commercial energy use from the distribution in population within parishes.

Industrial fuels (natural gas, coal, distillate fuel, kerosene, LPG, residual fuel, petroleum coke, and miscellaneous petroleum fuel) include activities such as manufacturing, construction, mining, and agriculture. The largest contributor for industrial fuels in terms of energy consumption is manufacturing (EPA 2011a), so the assumption used is the ratio of employees in the manufacturing and oil & gas extraction industries, as shown in Equation 6.

$$\left(\frac{industrial\,employment(parish)}{industrial\,employment(state)}\right) \times industrial\,emissions(state) \qquad \text{(Eq. 6)}$$

4.2.2.2 Mobile Energy Consumption

Estimating transportation emissions at the parish level include energy consumption from motor vehicles, public transit, rail, aviation, and marine. Many of these transportation-related sources and assumptions are also referenced in Shu et al. (2010). For motor vehicles, miles of roadway are used to downscale motor vehicle activity from the state level to parishes as road density, as indicated in Equation 7.

$$\left(\frac{roadway\,miles(parish)}{roadway\,miles(state)}\right) \times \left(\frac{land\,area(parish)}{land\,area(state)}\right) \times motor\,vehicle\,emissions(state) \qquad \text{(Eq.7)}$$

To account for the use of public transit and its emissions by parish, it is assumed that the number of employees who reported work commute by public transit in the SF-3 of the census data is a good proxy (Equation 8). Rail transportation emissions estimates are allocated using miles of tracks (Equation 9). Aviation emissions are currently in

$$\left(\frac{\#\,employee\,commute\,by\,public\,transit\,(parish)}{\#\,employee\,commute\,by\,public\,transit\,(state)}\right)\times public\,transit\,emissions\,(state) \qquad \text{(Eq. 8)}$$

$$\left(\frac{rail\,tracks\,miles\,(parish)}{rail\,tracks\,miles\,(state)}\right)\times\left(\frac{land\,area\,(parish)}{land\,area\,(state)}\right)\times rail\,emissions\,(state) \qquad \text{(Eq. 9)}$$

discussion in the literature with inconsistent results and uncertainties concerning how aviation contributes to GHG emissions at the local scale (Dorbian et al. 2010, Forster et al. 2006,Wuebbles et al. 2007). In light of this, a simple indicator is chosen with numbers of airports to determine a parish's influence on aviation emissions, as calculated in Equation 10.

$$\left(\frac{number\,of\,airports\,(parish)}{number\,of\,airports\,(state)}\right)\times aviation\,emissions\,(state) \qquad \text{(Eq. 10)}$$

Marine-related activities are related to water bodies; therefore, lengths of waterways are used as proxy for marine emissions (Equation 11).

$$\left(\frac{miles\,of\,waterway\,(parish)}{miles\,of\,waterway\,(state)}\right)\times\left(\frac{land\,area\,(parish)}{land\,area\,(state)}\right)\times marine\,emissions\,(state) \qquad \text{(Eq. 11)}$$

4.2.2.3 Agricultural Sources

The significant sources of agricultural emissions in N_2O and CH_4 are from manure management, enteric fermentation, and agricultural soils. Manure management emissions are driven by animal population and type, as well as manure management techniques used; therefore, to downscale to the parish level, livestock population data from the National Agricultural Statistics Service (USDA 2008) are used in Equation 12 as the allocation factor. The livestock population data for Louisiana includes cattle all, beef cows, and milk cows. Enteric fermentation emissions are also associated with livestock population, and use the same method as manure management in Equation 12.

$$\left(\frac{livestock\ population(parish)}{livestock\ population(state)}\right) \times emissions(state) \qquad \text{(Eq.12)}$$

The agricultural soils category usually represents a high contribution of N_2O emissions (EPA 2011a) from the result of livestock manure, fertilizer use, and plant residues. From these, a significant source is fertilizer use; therefore, crop production is determined to be an appropriate indicator for downscaling to parishes, as shown in Equation 13.

$$\left(\frac{crop\ production(parish)}{crop\ production(state)}\right) \times emissions(state) \qquad \text{(Eq. 13)}$$

4.2.2.4 Waste Management

Emissions from waste management come from two sources in landfills (solid waste management) and wastewater treatment. These are apportioned on a per capita basis using population estimates to estimate indirect emissions. Equation 14 assumes that individuals who generate wastes in a parish are directly contributing to the total emissions regardless of where the wastes are disposed.

$$\left(\frac{population(parish)}{population(state)}\right) \times waste\ emissions(state) \qquad \text{(Eq. 14)}$$

4.2.2.5 Industrial Processes

The greatest sources of emissions within the industrial processes sector are substitution of ozone depleting substances (ODS), iron and steel production, and cement manufacture. ODS substitutes are used to replace the several original ODSs that were identified to be harmful to the ozone according to the Montreal Protocol and Clean Air Act Amendments of 1990 (IPCC 2007). The EPA, however, recognizes that ODS substitutes are a heavy contributor to GHG concentrations, of which include chemicals used in air conditioners, fire extinguishers, refrigerators, foams, aerosols, etc. ODS substitutes can be downscaled from national scale estimates as the product of parish population and state per capita emissions, and converted to $MMTCO_2E$ (Equation 15).

$$\left(\frac{population(parish)}{population(nation)}\right) \times ODS\, substitutes\, emissions(state) \qquad \text{(Eq. 15)}$$

To characterize iron and steel production and cement manufacture emissions at the parish level, an assumption of the parish-state ratio of the number of establishments according to the North American Industry Classification System (NAICS) codes equal to parish-state emissions, as shown in Equation 16.

$$\left(\frac{\#\, establishments(parish)}{\#\, establishments(state)}\right) \times industrial\, processes\, CO_2\, emissions(state) \qquad \text{(Eq. 16)}$$

4.2.2.6 Fugitive Emissions from Fuel Systems

Fugitive emissions of $CH_4$from fuel systems are the result of natural gas and oil production, transmission, and distribution. To allocate these processes to the parish level, the ratio of total natural gas or petroleum consumption for a parish to the total natural gas or petroleum consumption for the state is calculated; assuming equal consumption from residential, commercial, and industrial sectors within parishes correlate with leaking emissions from the production, transmission, and distribution of those fuels. Equations 17 and 18 demonstrate the downscaling methods for natural gas and oil, respectively.

$$\left(\frac{total\,natural\,gas\,consumption\,(parish)}{total\,natural\,gas\,consumption\,(state)}\right)\times natural\,gas\,fugitive\,emissions\,(state) \quad \text{(Eq. 17)}$$

$$\left(\frac{total\,petroleum\,consumption\,(parish)}{total\,petroleum\,consumption\,(state)}\right)\times petroleum\,fugitive\,emissions\,(state) \quad \text{(Eq. 18)}$$

4.2.2.7 Land Use, Land-Use Change, and Forestry

The land use, land-use change, and forestry (LULUCF) sector is represented by carbon in agricultural soils, forest carbon, land-use change, and urban trees. Forest carbon is a good opportunity to sequester carbon (sink) from the atmosphere, usually expressed with negative (-) estimates. The amount of carbon sequestered by a state’s forests can be assumed to depend on the acreage and growth of forest land. Forest land includes parks, reservations, forest plantations, and private forests. The species mix (forest type) is required to factor in the difference in carbon sequestration per species. After each type per parish is calculated, they can then be summed across all types and parishes to obtain the state total. To account for land-use change, the growth of forest land can be determined with a comparison to previous years’ acreage and also with applying carbon stock factors for each species (amount of carbon stored per unit area). This is not expressed in Equation 19 to downscale forest carbon; it is assumed that these have been appropriately accounted for in the SIT when estimating the state-level baseline data.

$$\left(\frac{forest\,acerage\,by\,type\,(parish)}{forest\,acreage\,by\,type\,(state)}\right)\times forest\,carbon\,emissions\,(state) \quad \text{(Eq. 19)}$$

Urban trees include trees in parks, private property, along streets, and open green spaces in urbanized areas as defined in the U.S. Census Bureau. This can be downscaled by identifying the percentage of urbanized areas with tree coverage and applying the state emissions (or sequestration), as shown in Equation 20.

$$\left(\frac{urban\,area\,(parish)}{urban\,area\,(state)}\right)\times\left(\frac{\%\,tree\ cover\,(parish)}{\%\,tree\ cover\,(state)}\right)\times urban\,trees\,emissions\,(state) \qquad \text{(Eq. 20)}$$

CHAPTER 5: RESULTS AND DISCUSSION

5.1 State-Level GHG Emissions (Baseline Data)

For the entire state of Louisiana, gross emissions of GHG totaled 219.63 million metric tons of carbon dioxide equivalent ($MMTCO_2E$) in 2005. These emissions are summarized in Table 6 by source category. The table also compares emissions using the methods described in chapter four (latest version of EPA's State Inventory Tool [SIT]) and the inventory prepared in CES (2010). The net emissions were estimated to be 207.59 $MMTCO_2E$ when LULUCF is included to represent sequestration from natural sinks. Most of the GHG emissions (90.49 percent) resulted from stationary energy consumption, including residential, commercial, and industrial; and mobile energy consumption from transportation. Fugitive emissions and agriculture produced 5.93 percent and 1.93 percent, respectively. Industrial processes and waste management were the least, emitting 1.66 percent together. The results of each state-level category emissions estimates are listed in the appendix.

Table 6: Summary of Louisiana's 2005 Greenhouse Gas Emissions by Sector

Emissions Source Category	**Emissions ($MMTCO_2E$)**	**Percent Total (%)**	**CES, 2010 ($MMTCO_2E$)**
Stationary Energy (Residential)	19.71	8.97	19.13
Stationary Energy (Commercial)	15.09	6.87	13.39
Stationary Energy (Industrial)	112.05	51.02	110.97
Mobile Energy Consumption	51.89	23.63	49.74
Agriculture	4.24	1.93	6.44
Waste Management	1.03	0.47	1.15
Industrial Processes	2.60	1.19	13.42
Fugitive Emissions from Fuel Systems	13.02	5.93	13.38
Total Gross Emissions	**219.63**	**100**	**227.62**
Land Use, Land Use Change, and Forest	-12.04		-12.72
Total Net Emissions	**207.59**		**214.90**

5.2 Parish-Level GHG Emissions

5.2.1 Estimates from DVRPC Method

Parish-level GHG emissions estimated using the Delaware Valley Regional Planning Commission's (DVRPC) allocation method for the state of Louisiana are shown in Table 7. The results in the table present emissions in MMTCO$_2$E for all parishes in Louisiana according to source emission categories. Of the sixty-four (64) parishes in 2005, Orleans produced the most GHG emissions at 12.74 MMTCO$_2$E, while St. Helena produced the least at 0.04 MMTCO$_2$E. The average was 1.84, calculated from the net total of 117.46 MMTCO$_2$E. The results in Table 7 do not show emissions for the Mobile Energy Consumption category since the methods to estimate them were not reproducible (see Background chapter for explanation). If we had assumed that this category had been properly allocated fully from the state's estimate (51.89 MMTCO$_2$E), then the DVRPC method would have been able to characterize approximately 79% of the gross emissions for the state of Louisiana (173.87/219.59).

Table 7: 2005 Louisiana Parishes GHG Emissions (MMTCO$_2$E) Estimated Using DVRPC Method

County	Res. Energy	Comm. Energy	Indust. Energy	Ag	Waste	IP	FE	Gross*	LULUCF	Net*
Acadia	0.26	0.20	0.96	0.15	0.01	0.02	0.05	**1.64**	0.11	**1.53**
Allen	0.11	0.09	0.42	0.04	0.01	0.01	0.02	**0.70**	0.00	**0.70**
Ascension	0.34	0.26	1.31	0.02	0.02	0.03	0.06	**2.03**	0.08	**1.96**
Assumption	0.10	0.08	0.37	0.01	0.01	0.01	0.02	**0.59**	0.25	**0.35**
Avoyelles	0.18	0.14	0.68	0.19	0.01	0.01	0.03	**1.25**	0.58	**0.67**
Beauregard	0.15	0.11	0.54	0.05	0.01	0.01	0.03	**0.89**	0.19	**0.70**
Bienville	0.07	0.05	0.26	0.02	0.00	0.01	0.01	**0.42**	-0.08	**0.50**
Bossier	0.43	0.33	1.69	0.04	0.02	0.03	0.08	**2.63**	0.24	**2.39**
Caddo	1.11	0.86	4.45	0.07	0.06	0.09	0.20	**6.84**	0.30	**6.53**

(table continued)

Calcasieu	0.81	0.62	3.21	0.09	0.04	0.06	0.14	**4.98**	0.28	**4.70**
Caldwell	0.05	0.04	0.17	0.02	0.00	0.00	0.01	**0.28**	0.18	**0.10**
Cameron	0.04	0.03	0.16	0.07	0.00	0.00	0.01	**0.33**	0.00	**0.33**
Catahoula	0.05	0.04	0.18	0.14	0.00	0.00	0.01	**0.41**	0.18	**0.23**
Claiborne	0.07	0.06	0.27	0.02	0.00	0.01	0.01	**0.45**	-0.22	**0.67**
Concordia	0.09	0.07	0.33	0.16	0.00	0.01	0.02	**0.68**	0.00	**0.67**
De Soto	0.11	0.08	0.41	0.06	0.01	0.01	0.02	**0.70**	-0.26	**0.96**
East Baton Rouge	1.82	1.43	7.59	0.04	0.09	0.15	0.32	**11.43**	0.05	**11.38**
East Carroll	0.04	0.03	0.15	0.23	0.00	0.00	0.01	**0.47**	0.00	**0.46**
East Feliciana	0.09	0.07	0.35	0.04	0.00	0.01	0.02	**0.58**	-0.07	**0.65**
Evangeline	0.16	0.12	0.57	0.11	0.01	0.01	0.03	**1.00**	-0.02	**1.01**
Franklin	0.09	0.07	0.35	0.20	0.00	0.01	0.02	**0.74**	0.20	**0.55**
Grant	0.08	0.06	0.29	0.02	0.00	0.01	0.01	**0.48**	-0.01	**0.49**
Iberia	0.32	0.25	1.27	0.01	0.02	0.03	0.06	**1.95**	0.19	**1.77**
Iberville	0.15	0.11	0.57	0.03	0.01	0.01	0.03	**0.91**	0.33	**0.58**
Jackson	0.07	0.05	0.25	0.01	0.00	0.01	0.01	**0.40**	-0.04	**0.44**
Jefferson	2.01	1.54	7.90	0.00	0.10	0.16	0.35	**12.08**	-0.01	**12.08**
Jefferson Davis	0.14	0.10	0.51	0.15	0.01	0.01	0.02	**0.95**	-0.23	**1.18**
Lafayette	0.84	0.66	3.54	0.02	0.04	0.07	0.15	**5.32**	0.03	**5.29**
Lafourche	0.40	0.30	1.53	0.02	0.02	0.03	0.07	**2.37**	-0.05	**2.42**
La Salle	0.06	0.05	0.23	0.04	0.00	0.01	0.01	**0.41**	0.00	**0.41**
Lincoln	0.19	0.14	0.73	0.02	0.01	0.01	0.03	**1.14**	0.07	**1.07**
Livingston	0.40	0.30	1.47	0.02	0.02	0.03	0.07	**2.32**	0.19	**2.13**
Madison	0.06	0.05	0.22	0.21	0.00	0.00	0.01	**0.56**	0.42	**0.14**
Morehouse	0.14	0.10	0.50	0.28	0.01	0.01	0.02	**1.06**	0.13	**0.93**
Natchitoches	0.17	0.13	0.66	0.11	0.01	0.01	0.03	**1.13**	0.49	**0.64**
Orleans	2.14	1.64	8.41	0.00	0.11	0.17	0.38	**12.86**	0.11	**12.74**
Ouachita	0.65	0.50	2.59	0.03	0.03	0.05	0.11	**3.97**	0.01	**3.96**
Plaquemines	0.12	0.09	0.48	0.01	0.01	0.01	0.02	**0.74**	0.00	**0.74**
Pointe Coupee	0.10	0.08	0.37	0.17	0.01	0.01	0.02	**0.74**	-0.18	**0.93**
Rapides	0.56	0.43	2.22	0.10	0.03	0.04	0.10	**3.47**	0.75	**2.72**
Red River	0.04	0.03	0.15	0.04	0.00	0.00	0.01	**0.28**	0.03	**0.25**
Richland	0.09	0.07	0.34	0.16	0.00	0.01	0.02	**0.69**	0.18	**0.51**
Sabine	0.10	0.08	0.38	0.03	0.01	0.01	0.02	**0.62**	0.34	**0.28**
St. Bernard	0.30	0.22	1.08	0.00	0.02	0.02	0.05	**1.69**	0.02	**1.67**
St. Charles	0.21	0.16	0.84	0.01	0.01	0.02	0.04	**1.29**	-0.37	**1.66**
St. Helena	0.05	0.03	0.16	0.03	0.00	0.00	0.01	**0.28**	0.25	**0.04**
St. James	0.09	0.07	0.36	0.00	0.00	0.01	0.02	**0.55**	-0.07	**0.62**
St. John the Baptist	0.19	0.14	0.71	0.05	0.01	0.02	0.03	**1.16**	-0.04	**1.19**

(table continued)

St. Landry	0.39	0.29	1.44	0.16	0.02	0.03	0.07	**2.40**	-0.04	**2.44**
St. Martin	0.21	0.16	0.78	0.02	0.01	0.02	0.04	**1.24**	0.17	**1.07**
St. Mary	0.24	0.18	0.94	0.02	0.01	0.02	0.04	**1.45**	0.41	**1.04**
St. Tammany	0.84	0.64	3.21	0.00	0.04	0.07	0.15	**4.96**	-0.42	**5.38**
Tangipahoa	0.44	0.34	1.71	0.08	0.02	0.04	0.08	**2.71**	0.27	**2.44**
Tensas	0.03	0.02	0.11	0.15	0.00	0.00	0.01	**0.32**	0.21	**0.11**
Terrebonne	0.46	0.36	1.84	0.01	0.02	0.04	0.08	**2.81**	-0.35	**3.17**
Union	0.10	0.08	0.37	0.04	0.01	0.01	0.02	**0.61**	-0.09	**0.71**
Vermilion	0.24	0.18	0.88	0.17	0.01	0.02	0.04	**1.53**	-0.10	**1.63**
Vernon	0.23	0.18	0.86	0.02	0.01	0.02	0.04	**1.36**	-0.06	**1.42**
Washington	0.19	0.15	0.71	0.06	0.01	0.02	0.03	**1.17**	-0.01	**1.18**
Webster	0.18	0.14	0.69	0.02	0.01	0.01	0.03	**1.10**	0.06	**1.03**
West Baton Rouge	0.10	0.07	0.38	0.01	0.00	0.01	0.02	**0.59**	-0.05	**0.63**
West Carroll	0.05	0.04	0.20	0.11	0.00	0.00	0.01	**0.42**	-0.01	**0.43**
West Feliciana	0.07	0.05	0.26	0.02	0.00	0.01	0.01	**0.41**	0.01	**0.40**
Winn	0.07	0.06	0.28	0.01	0.00	0.01	0.01	**0.44**	-0.03	**0.47**
Louisiana	**19.71**	**15.11**	**76.86**	**4.23**	**1.03**	**1.57**	**3.47**	**121.98**	**4.52**	**117.46**

* Gross total and net total does not include mobile energy consumption category.
FE=Fugitive Emissions.
IP=Industrial Processes.
LULUCF=Land Use, Land-Use Change, and Forestry.

According to the DVRPC report, approximately ninety percent (90%) of the gross emissions were allocated to counties within the Delaware Valley region using a hybrid of bottom-up and top-down allocation methods developed for each emission source category. Although the estimates in Table 5 agree with the allocated emissions percentage of 90% for the referenced study area, the method did not translate well for the state of Louisiana. As previously mentioned, Louisiana is a highly energy-producing state, and the sources that were omitted from the DVRPC's allocation method represent 28.23% of the gross emissions (Table 8). Another issue is the use of bottom-up approaches for source categories of Agriculture, Industrial Processes, Fugitive Emissions, and LULUCF. The results tend to either overestimate or underestimate against the baseline state data. As Table 7 indicates, along with the assumption on Mobile Energy

Consumption's full allocation, approximately 79% of the state's gross emissions were allocated and downscaled to the state's sixty-four (64) parishes.

Table 8: Excluded Emission Sources from State Total Using DVRPC method

Emissions Source Category	**Source**	**Percentage excluded**
Industrial Energy	Residual Fuel	0.60%
Industrial Energy	Petroleum Coke	4.13%
Industrial Energy	Other Fuels	11.78%
Mobile Energy	Highway through traffic and airport traffic	5.39%
Mobile Energy	Direct Diesel Emissions from Transit Rail	0.00%
Mobile Energy	Indirect Emissions (elec) from transit rail	0.00%
Mobile Energy	Freight Rail	0.00%
Mobile Energy	Indirect Emissions (elec) from intercity rail	0.00%
Mobile Energy	Aviation	5.33%
Mobile Energy	Marine & Port-Related	0.03%
Industrial Processes	Cement Manufacture	0.00%
Industrial Processes	Iron & Steel Production	0.47%
Fugitive Emissions	Petroleum Systems	0.50%
	Total	**28.23%**

5.2.2 Volume-Preserved Estimates

Parish-level GHG emissions estimated using the volume-preserving method for the state of Louisiana are shown in Table 9. Of the sixty-four (64) parishes in 2005, East Baton Rouge produced the most GHG emissions at 14.97 $MMTCO_2E$, while East Carroll produced the least at 0.29 $MMTCO_2E$. The average was 3.17, calculated from the net total of 202.59 $MMTCO_2E$. A remainder of 4.96$MMTCO_2E$ (2.26% of the gross emissions) belongs to off-road vehicles emissions from the Mobile Energy Consumption category, of which was the only source not downscaled due to difficulty in defining emission drivers. Despite this, the volume-preserving method was able to characterize 97.74% of the state's gross emissions (214.66/219.63) and net total (214.66/207.59).

Table 9: 2005 Louisiana Parishes GHG Emissions ($MMTCO_2E$) Estimated Using Volume-Preserving Method

County	Res. Energy	Comm Energy	Indust Energy	Mobile Energy	Ag	Waste	IP	FE	Gross	LUL UCF	Net
Acadia	0.26	0.19	2.19	1.13	0.15	0.01	0.04	0.11	**2.87**	0.09	**2.77**
Allen	0.11	0.08	0.50	0.39	0.04	0.01	0.01	0.06	**1.22**	0.33	**0.89**
Ascension	0.34	0.26	3.72	1.06	0.02	0.02	0.06	0.22	**3.86**	0.10	**3.76**
Assumption	0.10	0.07	0.84	0.52	0.01	0.01	0.01	0.03	**1.06**	0.11	**0.95**
Avoyelles	0.19	0.13	0.62	0.75	0.19	0.01	0.02	0.08	**2.10**	0.23	**1.87**
Beauregard	0.14	0.11	0.99	0.85	0.05	0.01	0.02	0.06	**1.79**	0.56	**1.23**
Bienville	0.07	0.05	0.52	0.55	0.02	0.00	0.01	0.03	**1.01**	0.24	**0.77**
Bossier	0.45	0.33	2.46	0.70	0.04	0.02	0.06	0.28	**4.30**	0.22	**4.09**
Caddo	1.16	0.87	4.82	1.40	0.07	0.06	0.16	0.88	**11.91**	0.21	**11.69**
Calcasieu	0.82	0.63	4.99	1.23	0.09	0.04	0.11	0.59	**8.56**	0.26	**8.30**
Caldwell	0.05	0.03	0.32	0.50	0.02	0.00	0.00	0.02	**0.78**	0.18	**0.60**
Cameron	0.04	0.03	0.21	0.27	0.07	0.00	0.00	0.02	**0.62**	0.00	**0.62**
Catahoula	0.05	0.03	0.28	0.47	0.14	0.00	0.00	0.02	**0.89**	0.28	**0.60**
Claiborne	0.08	0.05	0.51	0.60	0.02	0.00	0.01	0.03	**1.09**	0.22	**0.87**
Concordia	0.09	0.07	0.40	0.78	0.16	0.00	0.01	0.04	**1.51**	0.17	**1.34**
De Soto	0.11	0.08	0.92	0.62	0.06	0.01	0.01	0.04	**1.36**	0.23	**1.12**
East Baton Rouge	1.82	1.49	8.24	1.46	0.04	0.09	0.25	1.77	**21.54**	0.18	**21.36**
East Carroll	0.04	0.03	0.06	0.48	0.23	0.00	0.00	0.01	**0.94**	0.57	**0.37**
East Feliciana	0.09	0.07	0.55	0.63	0.04	0.00	0.01	0.04	**1.24**	0.12	**1.12**
Evangeline	0.16	0.11	0.95	0.68	0.11	0.01	0.02	0.06	**1.67**	0.15	**1.53**
Franklin	0.09	0.07	0.39	0.95	0.21	0.00	0.01	0.04	**1.74**	0.05	**1.69**
Grant	0.08	0.06	0.63	0.56	0.02	0.00	0.01	0.02	**0.99**	0.18	**0.81**
Iberia	0.33	0.25	3.25	0.41	0.01	0.02	0.06	0.23	**3.22**	0.10	**3.12**
Iberville	0.15	0.11	1.11	0.32	0.03	0.01	0.02	0.10	**1.58**	0.26	**1.31**
Jackson	0.07	0.05	0.58	0.57	0.01	0.00	0.01	0.03	**0.98**	0.19	**0.78**
Jefferson	2.02	1.55	8.29	0.92	0.00	0.10	0.28	1.41	**18.31**	0.07	**18.25**
Jefferson Davis	0.14	0.10	1.08	0.96	0.15	0.01	0.01	0.06	**1.99**	0.04	**1.94**
Lafayette	0.82	0.69	7.61	1.63	0.02	0.04	0.14	0.86	**11.30**	0.08	**11.22**
Lafourche	0.40	0.30	3.75	0.35	0.02	0.02	0.05	0.24	**3.44**	0.11	**3.33**
La Salle	0.06	0.05	0.59	0.68	0.04	0.00	0.01	0.03	**1.11**	0.22	**0.89**
Lincoln	0.20	0.14	0.78	0.74	0.02	0.01	0.03	0.13	**2.33**	0.14	**2.19**
Livingston	0.39	0.29	3.27	0.69	0.02	0.02	0.05	0.14	**2.97**	0.24	**2.73**
Madison	0.06	0.04	0.17	0.75	0.21	0.00	0.00	0.03	**1.33**	0.11	**1.22**
Morehouse	0.14	0.10	0.73	0.57	0.28	0.01	0.02	0.05	**1.66**	0.15	**1.51**
Natchitoches	0.18	0.13	1.25	0.49	0.11	0.01	0.02	0.10	**1.93**	0.40	**1.54**
Orleans	2.08	1.65	3.52	1.59	0.00	0.11	0.25	1.49	**20.02**	0.04	**19.99**
Ouachita	0.65	0.51	2.95	0.97	0.03	0.03	0.10	0.50	**6.98**	0.19	**6.79**

(table continued)

Plaquemines	0.12	0.09	0.61	0.18	0.01	0.01	0.02	0.10	**1.40**	0.03	**1.37**
Pointe Coupee	0.11	0.07	0.60	0.58	0.17	0.01	0.01	0.04	**1.35**	0.18	**1.17**
Rapides	0.55	0.43	2.53	0.95	0.10	0.03	0.07	0.42	**6.09**	0.46	**5.63**
Red River	0.04	0.03	0.27	0.52	0.04	0.00	0.00	0.02	**0.80**	0.09	**0.71**
Richland	0.09	0.07	0.45	0.95	0.16	0.00	0.01	0.04	**1.71**	0.05	**1.66**
Sabine	0.10	0.07	0.91	0.61	0.03	0.01	0.01	0.04	**1.26**	0.26	**1.00**
St. Bernard	0.29	0.21	0.91	0.06	0.00	0.02	0.04	0.10	**1.70**	0.02	**1.68**
St. Charles	0.21	0.17	1.91	0.69	0.01	0.01	0.03	0.16	**2.62**	0.09	**2.53**
St. Helena	0.05	0.03	0.13	0.43	0.03	0.00	0.00	0.01	**0.67**	0.09	**0.58**
St. James	0.09	0.07	1.36	0.65	0.00	0.00	0.02	0.05	**1.35**	0.09	**1.26**
St. John the Baptist	0.18	0.14	1.58	0.48	0.05	0.01	0.02	0.09	**1.82**	0.07	**1.75**
St. Landry	0.39	0.28	2.02	1.34	0.16	0.02	0.05	0.17	**3.99**	0.23	**3.76**
St. Martin	0.21	0.15	2.09	0.69	0.02	0.01	0.03	0.07	**1.90**	0.23	**1.67**
St. Mary	0.24	0.18	2.28	0.39	0.02	0.01	0.05	0.18	**2.59**	0.70	**1.89**
St. Tammany	0.85	0.63	4.73	1.28	0.00	0.04	0.11	0.47	**7.52**	0.29	**7.23**
Tangipahoa	0.43	0.34	2.81	1.11	0.08	0.02	0.06	0.26	**4.64**	0.24	**4.41**
Tensas	0.03	0.02	0.08	0.80	0.15	0.00	0.00	0.01	**1.12**	0.11	**1.01**
Terrebonne	0.46	0.36	4.73	0.28	0.01	0.02	0.07	0.36	**4.59**	0.11	**4.48**
Union	0.10	0.07	0.86	0.66	0.04	0.01	0.01	0.04	**1.32**	0.27	**1.05**
Vermilion	0.23	0.17	2.26	0.86	0.17	0.01	0.03	0.10	**2.46**	0.02	**2.44**
Vernon	0.22	0.17	0.58	0.84	0.02	0.01	0.02	0.10	**2.35**	0.54	**1.81**
Washington	0.20	0.14	0.89	0.76	0.06	0.01	0.03	0.08	**1.98**	0.19	**1.79**
Webster	0.20	0.14	1.62	0.89	0.02	0.01	0.03	0.10	**2.21**	0.16	**2.05**
West Baton Rouge	0.10	0.07	0.76	0.79	0.01	0.00	0.02	0.07	**1.65**	0.04	**1.61**
West Carroll	0.06	0.04	0.19	0.78	0.11	0.00	0.00	0.02	**1.22**	0.01	**1.20**
West Feliciana	0.06	0.05	0.40	0.58	0.02	0.00	0.01	0.04	**1.10**	0.10	**1.00**
Winn	0.07	0.06	0.46	0.53	0.01	0.00	0.01	0.04	**1.05**	0.36	**0.70**
Louisiana	**19.71**	**15.09**	**112.05**	**46.93**	**4.24**	**1.03**	**2.60**	**13.02**	**214.66**	**12.07**	**202.59**

FE=Fugitive Emissions.
IP=Industrial Processes.
LULUCF=Land Use, Land-Use Change, and Forestry.

Figure 3 shows the distribution results of the net total of GHG emissions using both downscaling methods. The results share some similar results, such as the highest and lowest groups of emitters of GHGs and the relative distribution patterns. The volume-preserving results from Figure 3(b) displays slightly more disparity in emissions than the

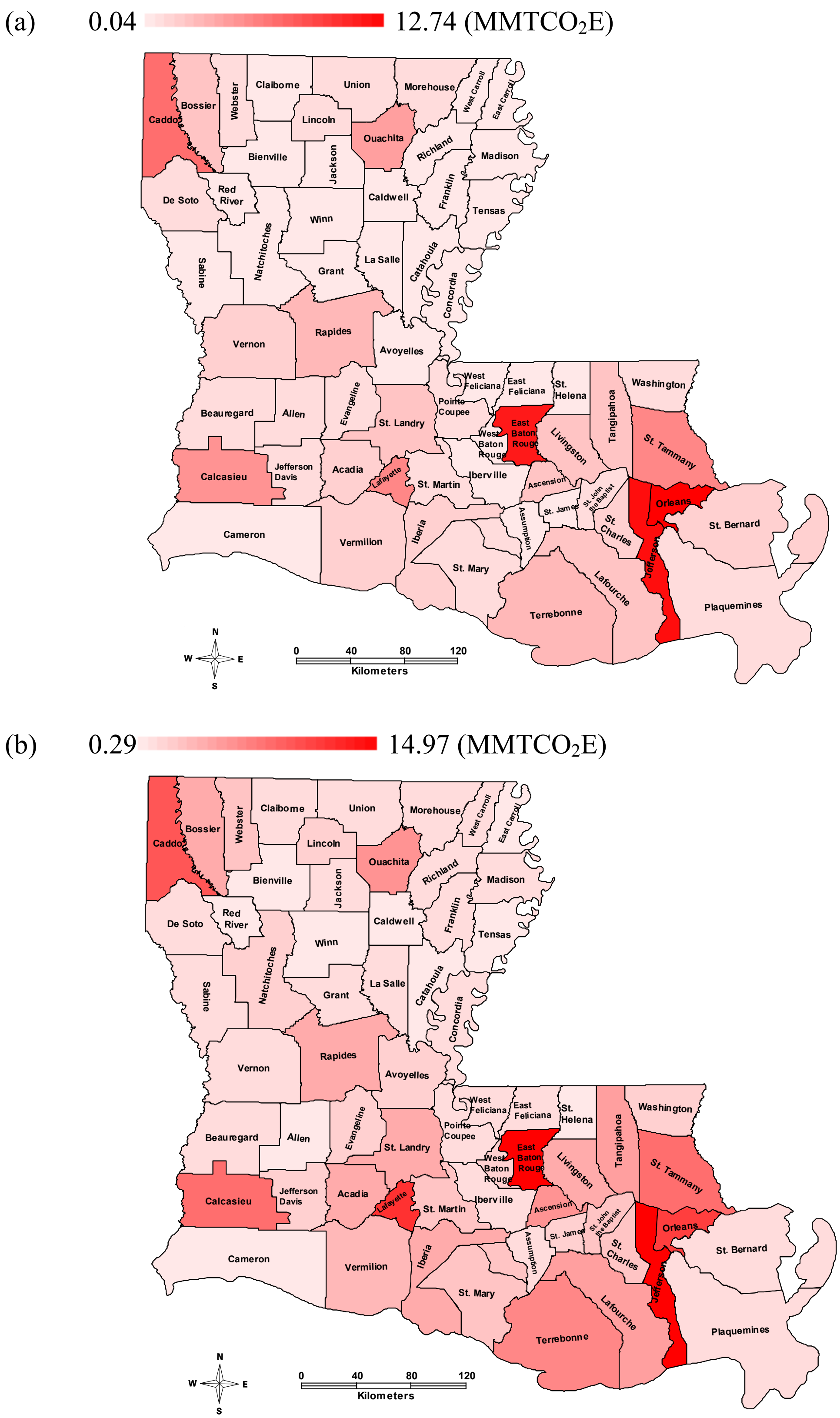

Figure 3: Net Total GHG Emissions at the Parish Level from (a) DVRPC and (b) Volume-Preserving Methods

DVRPC method shown in Figure 3(a). The highest group of emitters in both results included East Baton Rouge, Orleans, Jefferson, Caddo, St. Tammany, Calcasieu, and Lafayette; the lowest group included Red River, St. Helena, Catahoula, Caldwell, Tensas, and Cameron. A comparison of the ranks in the amount of GHG emissions for Louisiana parishes is shown in Table 10.

Table 10: Parish Emissions Sorted by Net Total Percentage Utilizing (a) DVRPC and (b) Volume-Preserving Methods

(a)

County	Net total %
Orleans	10.85%
Jefferson	10.29%
East Baton Rouge	9.69%
Caddo	5.56%
St. Tammany	4.58%
Lafayette	4.50%
Calcasieu	4.01%
Ouachita	3.37%
Terrebonne	2.70%
Rapides	2.32%
St. Landry	2.08%
Tangipahoa	2.07%
Lafourche	2.06%
Bossier	2.03%
Livingston	1.81%
Ascension	1.66%
Iberia	1.50%
St. Bernard	1.42%
St. Charles	1.41%
Vermilion	1.39%
Acadia	1.30%
Vernon	1.21%
St. John the Baptist	1.02%
Jefferson Davis	1.01%
Washington	1.00%
Lincoln	0.91%
St. Martin	0.91%
St. Mary	0.89%

(b)

County	Net total %
East Baton Rouge	7.39%
Jefferson	7.17%
Lafayette	5.79%
Orleans	5.26%
Caddo	4.54%
Calcasieu	4.07%
St. Tammany	3.86%
Terrebonne	3.06%
Ascension	2.76%
Ouachita	2.73%
Lafourche	2.47%
Tangipahoa	2.41%
Livingston	2.29%
Rapides	2.28%
Iberia	2.20%
St. Landry	2.07%
Bossier	2.04%
Acadia	1.96%
Vermilion	1.88%
St. Charles	1.53%
St. Martin	1.50%
Webster	1.40%
St. Mary	1.31%
St. John the Baptist	1.23%
Jefferson Davis	1.22%
St. James	1.07%
Washington	0.97%
Evangeline	0.96%

(table continued)

Webster	0.88%
Evangeline	0.86%
De Soto	0.82%
Morehouse	0.79%
Pointe Coupee	0.79%
Plaquemines	0.63%
Union	0.60%
Beauregard	0.60%
Allen	0.59%
Concordia	0.57%
Avoyelles	0.57%
Claiborne	0.57%
East Feliciana	0.55%
Natchitoches	0.54%
West Baton Rouge	0.54%
St. James	0.53%
Iberville	0.49%
Franklin	0.47%
Richland	0.44%
Bienville	0.43%
Grant	0.42%
Winn	0.40%
East Carroll	0.39%
Jackson	0.37%
West Carroll	0.37%
La Salle	0.35%
West Feliciana	0.34%
Assumption	0.29%
Cameron	0.28%
Sabine	0.24%
Red River	0.21%
Catahoula	0.19%
Madison	0.12%
Tensas	0.09%
Caldwell	0.08%
St. Helena	0.03%
Louisiana	**100.00%**

Lincoln	0.94%
Natchitoches	0.94%
West Baton Rouge	0.88%
Avoyelles	0.87%
Morehouse	0.85%
Richland	0.85%
Franklin	0.84%
Beauregard	0.82%
De Soto	0.80%
St. Bernard	0.80%
Iberville	0.78%
Sabine	0.76%
Union	0.75%
Assumption	0.73%
Vernon	0.70%
Pointe Coupee	0.69%
Concordia	0.68%
East Feliciana	0.65%
La Salle	0.61%
Grant	0.60%
West Carroll	0.59%
Madison	0.57%
Plaquemines	0.55%
Jackson	0.55%
Claiborne	0.53%
West Feliciana	0.52%
Bienville	0.50%
Tensas	0.49%
Allen	0.43%
Winn	0.41%
Red River	0.41%
Caldwell	0.37%
Catahoula	0.35%
Cameron	0.32%
St. Helena	0.30%
East Carroll	0.14%
Louisiana	**100.00%**

The results from the volume-preserving method for each emissions source category are shown in Figures 4-12 below. Figures 4-6 represent the distribution of emissions for stationary energy consumption in the residential, commercial, and industrial sectors, respectively. Orleans Parish emitted the most in the residential and commercial sectors (2.08 and 1.65), while East Baton Rouge Parish emitted the most in the industrial sector (8.24). In all sectors in stationary energy consumption, Tensas Parish registered the fewest emissions (0.03 in residential, 0.02 in commercial, and 0.08 in industrial). These emissions include direct emissions from site-specific fuel use and indirect emissions from electricity consumption measurements.

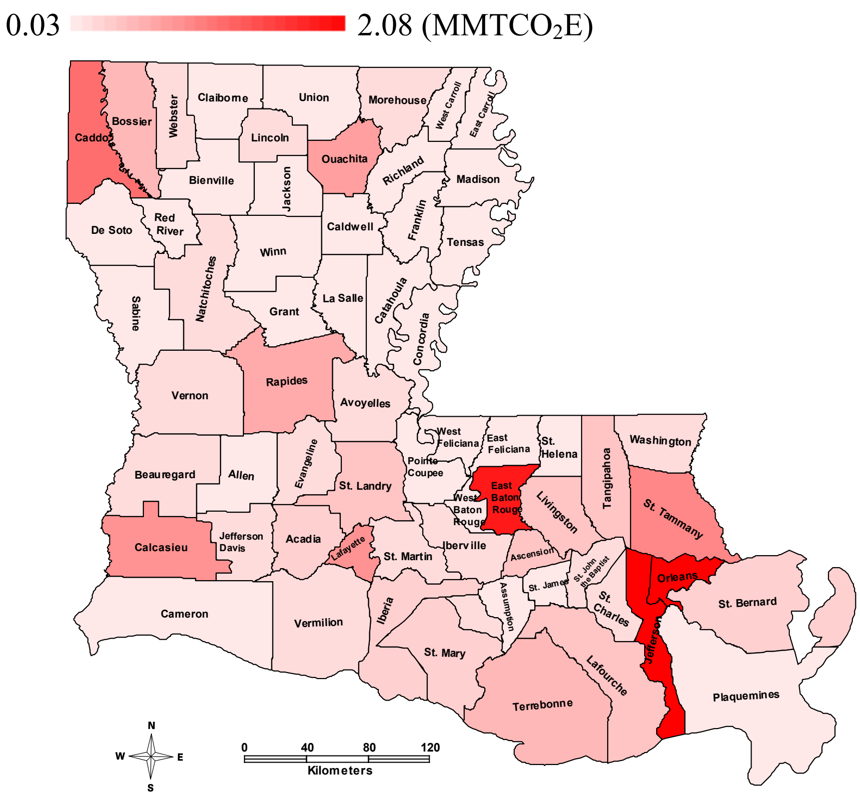

Figure 4: 2005 Louisiana Parishes Residential Sector Volume-Preserved GHG Emissions

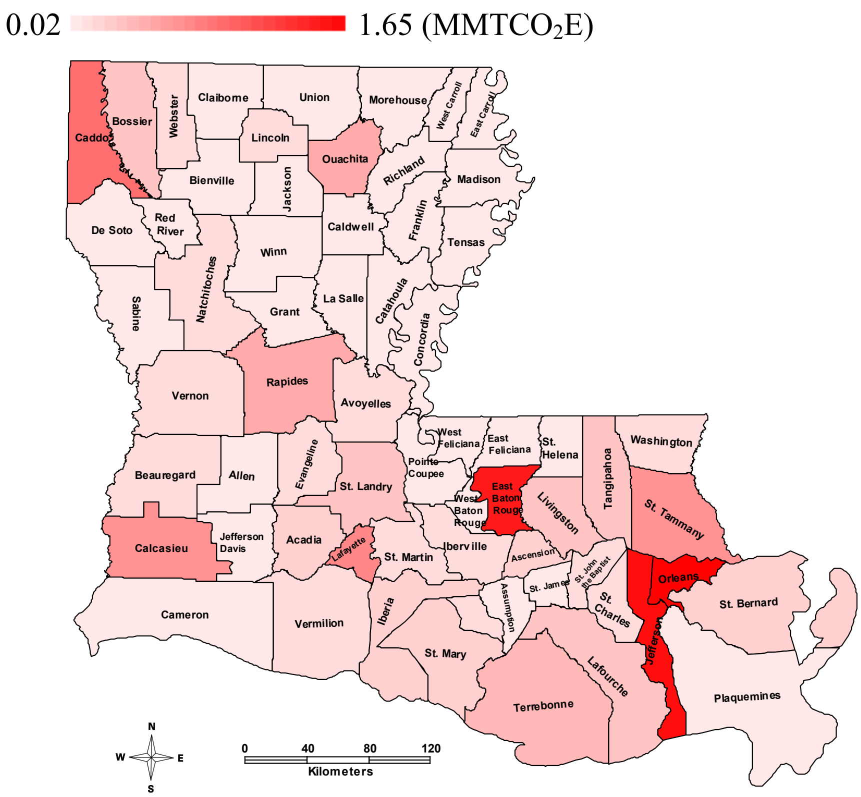

Figure 5: 2005 Louisiana Parishes Comm. Sector Volume-Preserved GHG Emissions

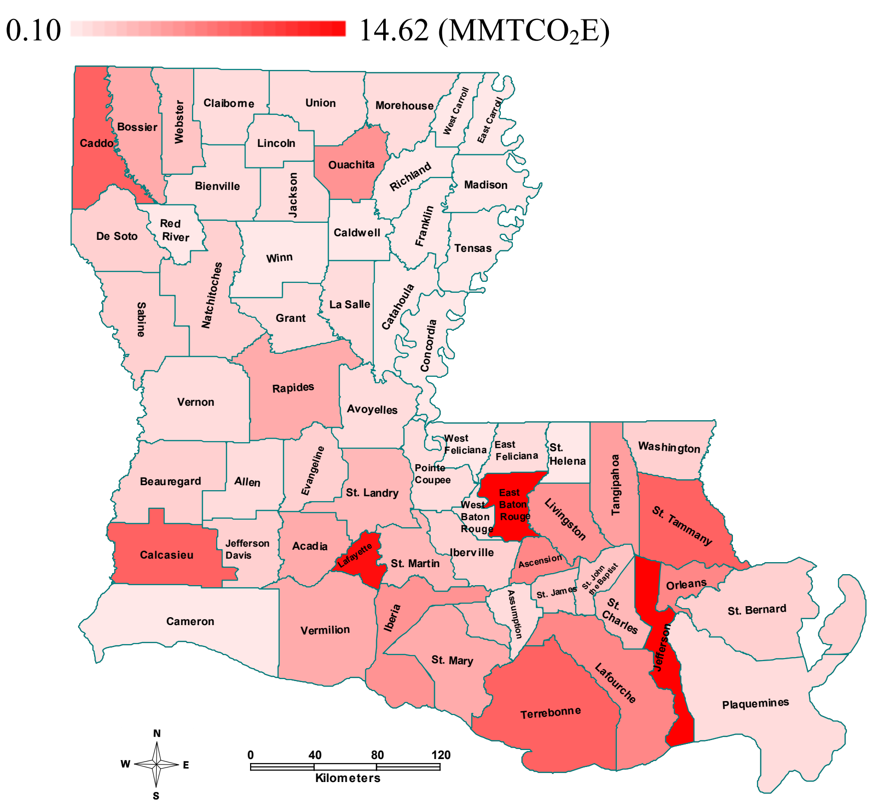

Figure 6: 2005 Louisiana Parishes Industrial Sector Volume-Preserved GHG Emissions

In the Mobile Energy Consumption source category as shown in Figure 7, Lafayette Parish produced the most emissions at 1.63 $MMTCO_2E$, followed closely by Orleans (1.60) and East Baton Rouge (1.46). The least emitting parish is St. Bernard at 0.062 $MMTCO_2E$. Included sources were road traffic, public transit, rail, aviation, and marine-related activities.

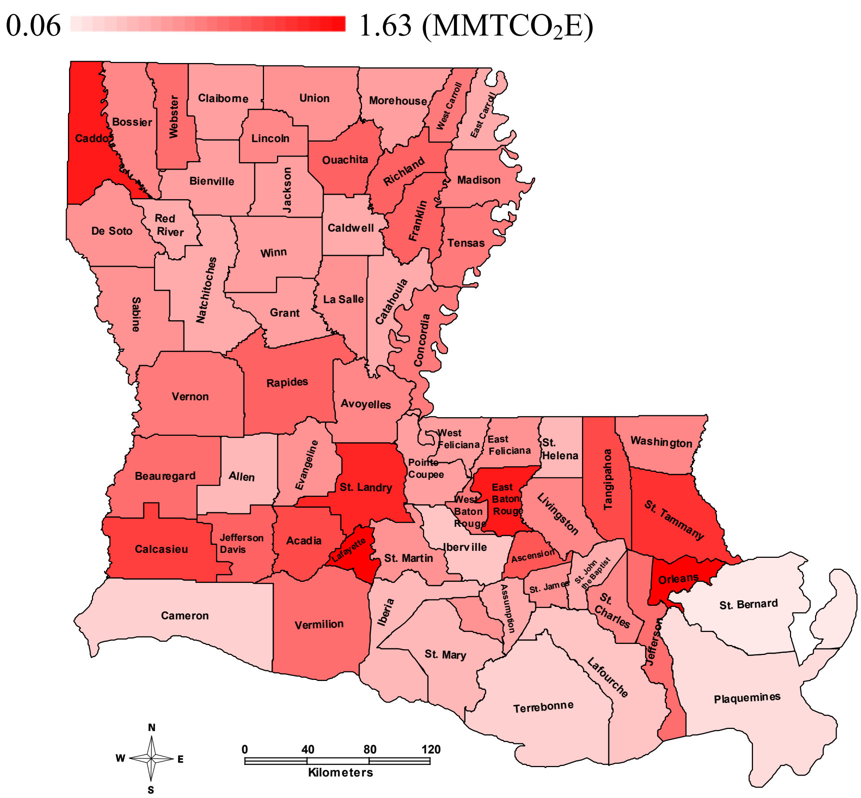

Figure 7: 2005 Louisiana Parishes Mobile Energy Volume-Preserved GHG Emissions

Figure 8 displays emissions for Agricultural emissions associated with manure management, enteric fermentation, and agricultural soils. In 2005, Morehouse Parish emitted the most GHG emissions, followed by East Carroll, Madison, and Franklin. The least emitting parishes were Orleans, St. James, St. Bernard, St. Tammany, and Jefferson.

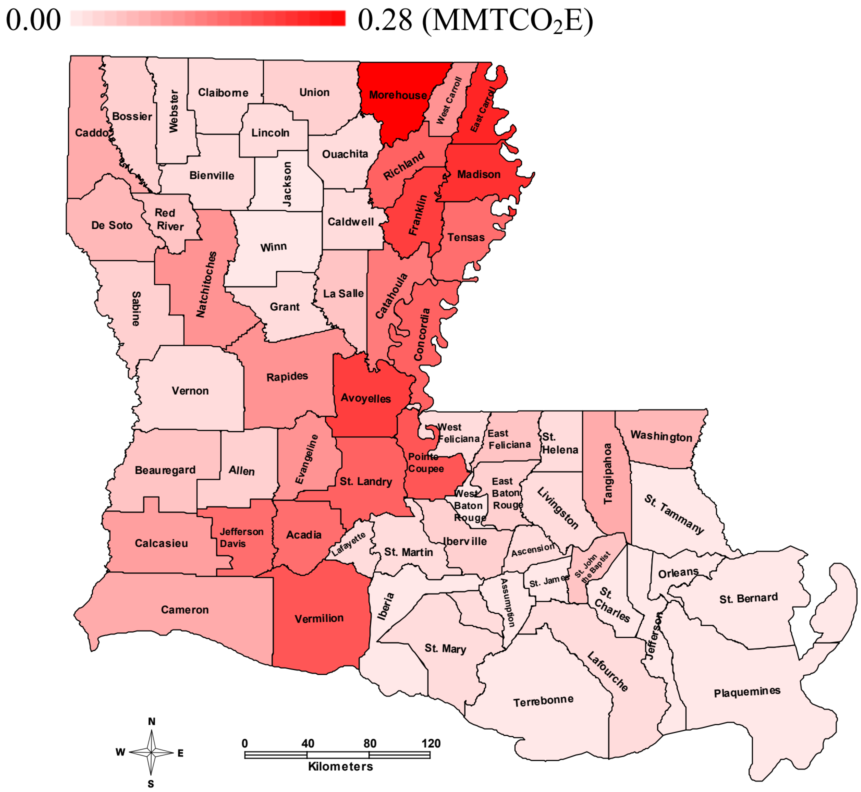

Figure 8: 2005 Louisiana Parishes Agricultural Volume-Preserved GHG Emissions

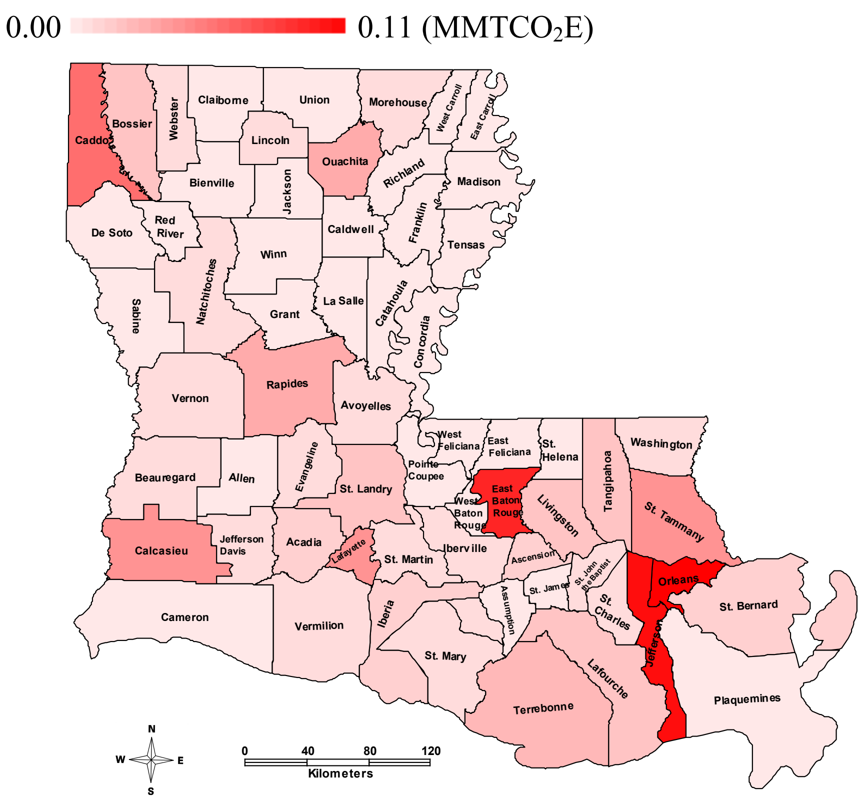

Figure 9: 2005 Louisiana Parishes Waste Category Volume-Preserved GHG Emissions

Parishes that generated the most Waste GHG emissions (Figure 9) from both indirectly contributing to landfills and wastewater treatments were Orleans (0.11), Jefferson (0.11), and East Baton Rouge (0.1). The least amount of Waste emissions was Tensas Parish (0.00).

The Industrial Processes category is influenced by cement manufacturing, iron and steel production, and ozone-depleting substances (ODS) substitutes. Figure 10 illustrates that Jefferson (0.28), East Baton Rouge (0.25), and Orleans (0.25) were the highest contributors in these processes, excluding cement manufacturing (there are no cement manufacturing activities in Louisiana). Tensas had the least amount of industrial processes activities at 0.00.

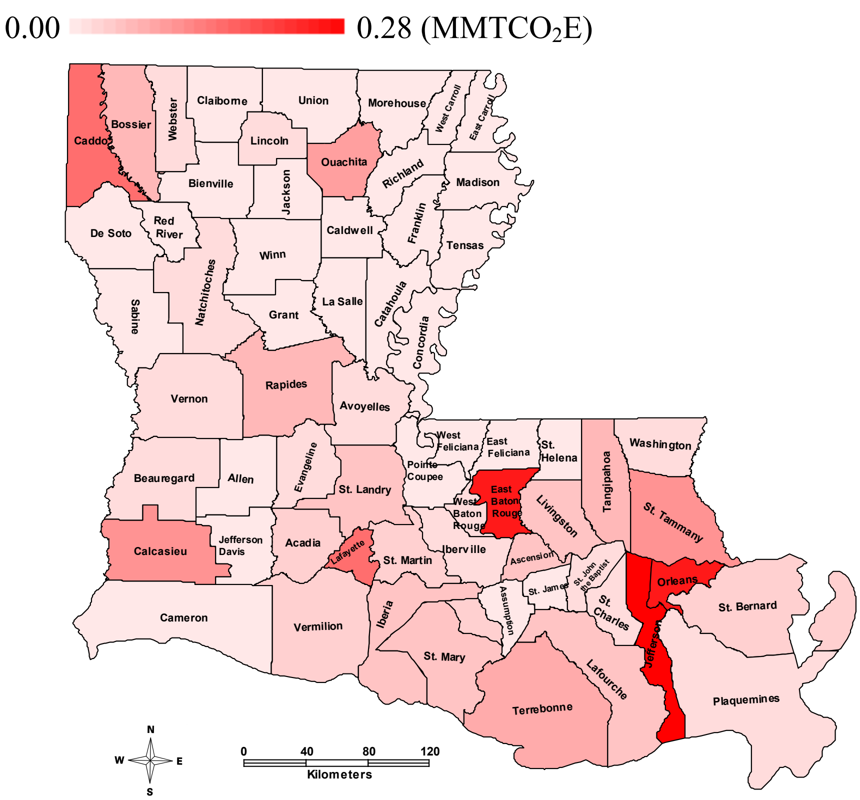

Figure 10:2005 Louisiana Parishes Industrial Processes Volume-Preserved GHG Emissions

The production, transportation, and distribution of natural gas and petroleum systems can result in fugitive GHG emissions, as shown in Figure 11. In this emissions source category, East Baton Rouge, Orleans, and Jefferson emitted the most GHGs at 1.77, 1.49, and 1.41, respectively. St. Helena and Tensas both emitted the lowest at 0.01.

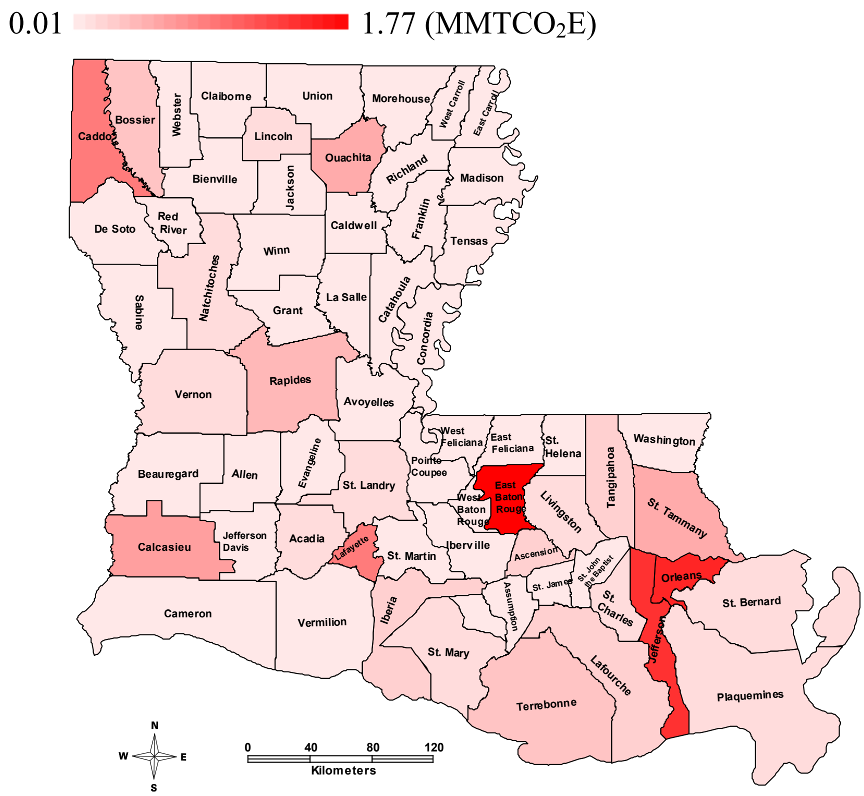

Figure 11: 2005 Louisiana Parishes Fugitive Emissions Category Volume-Preserved GHG Emissions

Finally, the Land Use, Land-Use Change, and Forestry (LULUCF) category represents the amount of carbon sequestered from the atmosphere suggested by the amount of forest carbon and urban trees within an area. Figure 12 shows that the parishes of St. Mary, East Carroll, Beauregard, and Vernon sequestered the most carbon, while Cameron, West Carroll, and St. Bernard were the least.

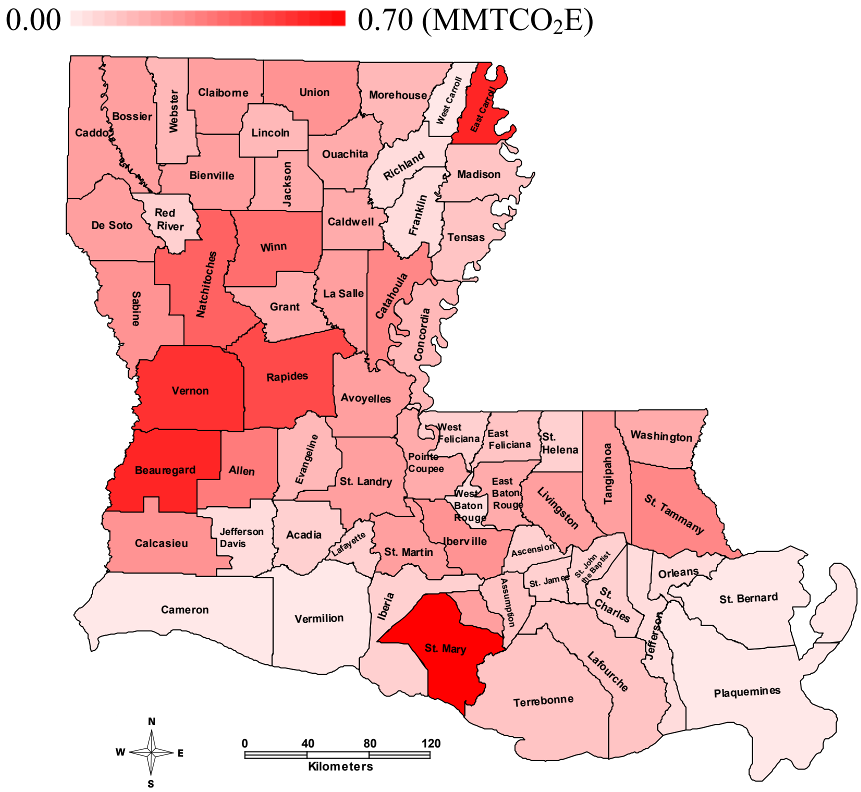

Figure 12: 2005 Louisiana Parishes Land Use, Land-Use Change, and Forestry Category Volume-Preserved GHG Emissions

In an attempt to provide some validation to the results provided by the volume-preserving method at the parish level, we compared the emission estimates to a greenhouse gas report prepared for Orleans Parish in 2009, with the years of 1998 and 2007 as baseline years (City of New Orleans 2009). Table 11 shows fairly consistent estimates produced by the volume-preserving method compared to the generally more accurate bottom-up inventorying approach conducted for Orleans Parish in both 1998 and 2007 using ICLEI's Clean Air & Climate Protection (CACP) software. The DVRPC method significantly overestimates the Industrial sector, and the total reflects this overestimation despite not having the Transportation emissions included due to irreproducible methods. The sharp difference in the residential sector is attributed to one of the largest population decline that any major United States city has experienced after a natural disaster event with Hurricane Katrina, and the 2007 results were only used for temporal and cultural reference. Compared to the bottom-up emissions total in 1998, the top-down, volume-preserving method slightly overestimated the total GHG emissions by 0.83 $MMTCO_2E$.

Table 11: Comparison of Net Total GHG Emissions for Orleans Parish

Sector	**N.O. ($MMTCO_2E$), 1998[1]**	**N.O. ($MMTCO_2E$), 2007[1]**	**DVRPC ($MMTCO_2E$), 2005[2]**	**VP ($MMTCO_2E$), 2005[3]**
Residential	2.2	0.91	2.14	2.08
Commercial	1.91	1.19	1.64	1.65
Industrial	0.59	0.45	8.41	3.52
Transportation	3.3	1.89	N/A	1.59
Waste	0.12	0.01	0.11	0.11
Total	**8.12**	**4.535**	**12.30**	**8.95**

[1]Estimates for Orleans Parish as referenced in City of New Orleans (2009).
[2]Estimates derived from the DVRPC method for Orleans Parish.
[3]Estimates derived from the volume-preserving method for Orleans Parish.

5.2.2.1 Caveats

The results from the proposed method utilizing proportional, volume-preserving downscaling has some key caveats. Aggregated data (e.g., fuel sales, population, forest species mix, vehicle miles traveled) from data sources were assumed to be accurate with no further quality-assurance performed, but they usually contain some errors and uncertainties, especially at sub-state levels. Some assumptions defined to link emission drivers to activities were based on bottom-up approaches that are not yet fully understood and mature; some were simply omitted, e.g., the non-road mobile combustion emission source was omitted from the estimations due to difficulty in characterizing the source at the parish level. There is also a needfor more bottom-up reference sources in the state to help iteratively check for the consistency of the results, including accounting for the year that was chosen for the study.

CHAPTER 6: CONCLUSION

The objective of this thesis is to estimate county-level greenhouse gas emissions (GHG) for all contiguous counties within a state by addressing issues of spatial resolution, accuracy, and relationships. An established method was used to obtain a state-level baseline data, of which was then downscaled to parish levels using different methods by taking advantage of the GHG emissions relationships between the state-parish scales. The state-level baseline data was estimated using the State Inventory Tool (SIT) developed with established guidelines by the Environmental Protection Agency (EPA). The downscaled county-level estimates for each sector and source were produced using two methods: (1) the Delaware Valley Regional Planning Commission (DVRPC) method and the (2) volume-preserving method.

The Louisiana state-level estimates produced by the latest version of the SIT were slightly less than the estimates reported in the Louisiana Greenhouse Gas Inventory (CES 2010) due to including indirect emissions from electricity consumption and applying updated emission factors. Distinguishing the indirect emissions allow local mitigation across all electricity consuming sectors. The new estimates provided a more accurate baseline data that are sectioned in a manner that improved the translation to individual parishes when downscaling emissions. The parish-level emissions for Louisiana estimated using the DVRPC method accounted for only approximately 79% of the state-level emissions, even with an assumed full allocation of the irreproducible transportation sector. This can be attributed to source omissions in the method that would have accounted for 28.23% of the gross emissions in Louisiana. The parish-level emissions for

Louisiana estimated using the volume-preserving method accounted for 97.74% of the state-level emissions, effectively downscaling most state-level emissions processes to all 64 parishes. The accuracy of the downscaling technique was also evaluated by comparing the 2005 estimates to1998 and 2007 bottom-up inventories developed for Orleans Parish (City of New Orleans 2009). This confirmed that the volume-preserving estimation was more consistent to the bottom-up inventories than the estimates derived from the DVRPC method.

The method proposed in this thesis attempted to characterize all GHG emissions for contiguous parishes within the state of Louisiana to the extent practicable, while maintaining the scientific integrity of established guidelines. The volume-preserving principle used in this method to proportionately downscale state emissions to parishes improves existing approaches by characterizing most of the emission measurements at the parish level, enabling resource-limited state and local governmental entities interested in managing local GHG emissions for planning, reduction, or mitigation in a simpler and less time-consuming manner. The results at the county scale can also be used to target specific sources or sectors in order to improve energy efficiency, leading to sustainable growth. The volume-preserving principle applied in the method helps maintain the data resolution of the original state data, effectively allocating nearly all of the emissions by sector and source. Although the parish (county) spatial scale serves as a good starting point, future studies can further downscale the emissions to finer scales with more data and better assumptions through more detailed correlation/regression analyses.

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APPENDIX: DETAILED STATE-LEVEL GHG EMISSIONS

Table 12: Summary of Agriculture Emissions for Louisiana (SIT)

Emissions ($MMTCO_2$ Eq.)

	2005
Enteric Fermentation	1.312
Manure Management	0.181
Ag Soils	2.751
Rice Cultivation	1.389
Agricultural Residue Burning	0.019
TOTAL	**5.652**

Emissions by Gas ($MMTCH_4$ or $MMTN_2O$)

	2005
Methane	**0.135**
Enteric Fermentation	0.062
Manure Management	0.006
Rice Cultivation	0.066
Agricultural Residue Burning	0.001
Nitrous Oxide	**0.009**
Manure Management	0.000
Ag Soils	0.009
Agricultural Residue Burning	0.000

Nitrous Oxide Emissions from Ag Soils (metric tons N_2O)

	2005
Direct	**7,635**
Fertilizers	2,503
Crop Residues	812
N-Fixing Crops	1,000
Histosols	-
Livestock	3,320
Indirect	**1,238**
Fertilizers	278
Livestock	187
Leaching/Runoff	773
Fertilizer Runoff/Leached	563
Manure Runoff/Leached	210
TOTAL	**8,874**

Table 13: Summary of Direct CO_2 Emissions from Fossil Fuels for Louisiana (SIT)

$MMTCO_2E$	**2005**
Residential	2.47
Coal	-
Petroleum	0.19
Natural Gas	2.28
Other	-
Commercial	2.05
Coal	-
Petroleum	0.66
Natural Gas	1.39
Other	-
Industrial	95.16
Coal	0.15
Petroleum	45.90
Natural Gas	49.11
Other	-
Transportation	51.06
Coal	-
Petroleum	48.74
Natural Gas	2.32
Other	-
Electric Power	42.75
Coal	23.66
Petroleum	3.53
Natural Gas	15.56
Other	-
International Bunker Fuels	0.02
Petroleum	0.02
TOTAL	193.48
Coal	23.81
Petroleum	99.02
Natural Gas	70.65
Other	-

Table 14: Summary of Methane Emissions from Coal Mining for Louisiana (SIT)

Emissions ($MTCO_2E$)

	2005
Coal Mining	42,950
Abandoned Coal Mines	-
Vented	-
Sealed	-
Flooded	-

Emissions by Gas ($MTCH_4$)

	2005
Coal Mining	2,045
Abandoned Coal Mines	-
Vented	-
Sealed	-
Flooded	-

Table 15: Summary of Electricity Consumption Emissions for Louisiana (SIT)

$MMTCO_2E$	**2005**
Residential	17.22
Space Heating	1.28
Air-conditioning	4.71
Water Heating	1.99
Refrigeration	1.65
Other Appliances and Lighting	7.60
Commercial	13.03
Space Heating	0.43
Cooling	2.54
Ventilation	1.50
Water Heating	0.40
Lighting	4.58
Cooking	0.12
Refrigeration	1.41
Office Equipment	0.17
Computers	0.49

(table continued)

Other	1.38
Industrial	16.24
Indirect Uses-Boiler Fuel	*0.08*
Conventional Boiler Use	0.05
CHP and/or Cogeneration Process	0.02
Direct Uses-Total Process	*13.03*
Process Heating	1.87
Process Cooling and Refrigeration	1.17
Machine Drive	8.35
Electro-Chemical Processes	1.59
Other Process Use	0.05
Direct Uses-Total Nonprocess	*2.66*
Facility HVAC	1.43
Facility Lighting	0.96
Other Facility Support	0.23
Onsite Transportation	0.02
Other Nonprocess Use	0.02
Other	*0.47*
Transportation	0.01
Automated Guideway	-
Bus (charged batteries)	-
Cable Car	-
Commuter Rail	-
Heavy Rail	-
Inclined Plane	-
Light Rail	0.01
Trolleybus	-
Other	-

(table continued)

TOTAL	**46.50**
Residential	17.22
Commercial	13.03
Industrial	16.24
Transportation	0.01

Table 16: Summary of Industrial Processes Emissions for Louisiana (SIT)

	2005
Carbon Dioxide Emissions	4,337,361
Cement Manufacture	-
Lime Manufacture	-
Limestone and Dolomite Use	9,570
Soda Ash	39,137
Ammonia & Urea	3,254,548
Iron & Steel Production	1,034,107
Nitrous Oxide Emissions	-
Nitric Acid Production	-
Adipic Acid Production	-
HFC, PFC, and SF_6 Emissions	1,865,192
ODS Substitutes	1,570,047
Semiconductor Manufacturing	-
Magnesium Production	-
Electric Power Transmission and Distribution Systems	295,146
HCFC-22 Production	-
Aluminum Production	-
Total Emissions	6,202,553

Table 17: Summary of LULUCF Emissions for Louisiana (SIT)

Emissions* ($MMTCO_2E$)

	2005
Forest Carbon Flux	(11.24)
Aboveground Biomass	0.87
Belowground Biomass	0.16
Dead Wood	0.41
Litter	0.31
Soil Organic Carbon	(2.84)
Total wood products and landfills	(10.16)
Liming of Agricultural Soils	-
Urea Fertilization	0.07
Urban Trees	(0.96)
Landfilled Yard Trimmings and Food Scraps	-
Forest Fires	-
CH_4	-
N_2O	-
N_2O from Settlement Soils	0.09
Total	**(12.04)**

*** Note that parentheses indicate net sequestration.**

Emissions (MMTCE)*

	2005
Forest Carbon Flux	(3.06)
Aboveground Biomass	0.24
Belowground Biomass	0.04
Dead Wood	0.11
Litter	0.08
Soil Organic Carbon	(0.77)
Total Wood products and landfills	(2.77)
Liming of Agricultural Soils	-
Urea Fertilization	0.02
Urban Trees	(0.26)
Landfilled Yard Trimmings and Food Scraps	-
Forest Fires	-
CH_4	-
N_2O	-
N_2O from Settlement Soils	0.02
Total	**(3.28)**

*** Note that parentheses indicate net sequestration.**

Table 18: Summary of Mobile Energy Combustion Emissions for Louisiana (SIT)

Total CH_4 and N_2O Emissions from Mobile Sources ($MTCO_2E$)

Fuel Type/Vehicle Type	
Gasoline Highway	**2005**
Passenger Cars	**831,875**
Light-Duty Trucks	457,734
Heavy-Duty Vehicles	348,530
Motorcycles	24,700
Diesel Highway	912
Passenger Cars	**8,184**
Light-Duty Trucks	72
Heavy-Duty Vehicles	350
Non-Highway	7,762
Boats	**209,041**
Locomotives	64,290
Farm Equipment	3,842
Construction Equipment	8,270
Aircraft	6,993
Other*	117,419
Alternative Fuel Vehicles	8,227
Light Duty Vehicles	**2,443**
Heavy Duty Vehicles	744
Buses	1,485
Total	213

* "Other" includes snowmobiles, small gasoline powered utility equipment, heavy-duty gasoline powered utility equipment, and heavy-duty diesel powered utility equipment.

CH_4 Emissions from Mobile Sources ($MTCO_2E$)

Fuel Type/Vehicle Type	
Gasoline Highway	**2005**
Passenger Cars	**45,558**
Light-Duty Trucks	26,452
Heavy-Duty Vehicles	16,551
Motorcycles	2,189
Diesel Highway	366
Passenger Cars	**538**
Light-Duty Trucks	2

(table continued)

Heavy-Duty Vehicles	15
Non-Highway	521
Boats	**22,328**
Locomotives	10,480
Farm Equipment	671
Construction Equipment	2,282
Aircraft	925
Other*	6,882
Alternative Fuel Vehicles	1,088
Light Duty Vehicles	**611**
Heavy Duty Vehicles	184
Buses	336
Total	92

* "Other" includes snowmobiles, small gasoline powered utility equipment, heavy-duty gasoline powered utility equipment, and heavy-duty diesel powered utility equipment.

N_2O Emissions from Mobile Sources ($MTCO_2E$)

Fuel Type/Vehicle Type	
Gasoline Highway	**2005**
Passenger Cars	**786,317**
Light-Duty Trucks	431,282
Heavy-Duty Vehicles	331,979
Motorcycles	22,510
Diesel Highway	546
Passenger Cars	**7,646**
Light-Duty Trucks	70
Heavy-Duty Vehicles	335
Non-Highway	7,241
Boats	**186,713**
Locomotives	53,810
Farm Equipment	3,171
Construction Equipment	5,988
Aircraft	6,068
Other*	110,537
Alternative Fuel Vehicles	7,139
Light Duty Vehicles	**1,831**
Heavy Duty Vehicles	561
Buses	1,149
Total	121

(table continued)

* "Other" includes snowmobiles, small gasoline powered utility equipment, heavy-duty gasoline powered utility equipment, and heavy-duty diesel powered utility equipment.

CH_4 Emissions from Mobile Sources (Gigagrams)

Fuel Type/Vehicle Type	
Gasoline Highway	**2005**
Passenger Cars	**2.2**
Light-Duty Trucks	1.3
Heavy-Duty Vehicles	0.8
Motorcycles	0.1
Diesel Highway	0.0
Passenger Cars	**0.0**
Light-Duty Trucks	0.0
Heavy-Duty Vehicles	0.0
Non-Highway	0.0
Boats	**1.1**
Locomotives	0.5
Farm Equipment	0.0
Construction Equipment	0.1
Aircraft	0.0
Other*	0.3
Alternative Fuel Vehicles	0.1
Light Duty Vehicles	**0.0**
Heavy Duty Vehicles	0.0
Buses	0.0
Total	0.0

* "Other" includes snowmobiles, small gasoline powered utility equipment, heay-duty gasoline powered utility equipment, and heavy-duty diesel powered utility equipment.

N_2O Emissions from Mobile Sources (Gigagrams)

Fuel Type/Vehicle Type	
Gasoline Highway	**2005**
Passenger Cars	**2.5**
Light-Duty Trucks	1.4
Heavy-Duty Vehicles	1.1
Motorcycles	0.1
Diesel Highway	0.0
Passenger Cars	**0.0**
Light-Duty Trucks	0.0
Heavy-Duty Vehicles	0.0
Non-Highway	0.0
Boats	**0.6**
Locomotives	0.2

(table continued)

Farm Equipment	0.0
Construction Equipment	0.0
Aircraft	0.0
Other*	0.4
Alternative Fuel Vehicles	0.0
Light Duty Vehicles	**0.0**
Heavy Duty Vehicles	0.0
Buses	0.0
Total	0.0

* "Other" includes snowmobiles, small gasoline powered utility equipment, heay-duty gasoline powered utility equipment, and heavy-duty diesel powered utility equipment.

Table 19: Summary of Natural Gas and Oil Systems Emissions for Louisiana (SIT)

Emissions ($MMTCO_2$ Eq.)

	2005
Natural Gas	4.95
Oil	1.10

Emissions by Gas ($MTCH_4$)

	2005
Natural Gas	223,607
Production	223,607
Transmission	-
Distribution	-
Oil	52,385

Emissions by Gas ($MMTCO_2$)

	2005
Natural Gas Flaring	0.25

Table 20: Summary of Waste Management Emissions for Louisiana (SIT)

Total Emissions from Landfills and Waste Combustion (MMTCO$_2$E)*

	2005
CH_4	0.453
CO_2	0.140
N_2O	0.003
Total	**0.596**

*** When default flaring and LFGTE activity data are utilized for AZ, DE, ID, NH, PA, RI, and VT, landfill methane avoided is greater than landfill methane produced. This is a result of using various sources of default data.**

CH_4 Emissions from Landfills (MTCO$_2$E)

	2005
Potential CH_4	**3,623,486**
MSW Generation	3,386,435
Industrial Generation	237,050
CH_4 Avoided	**(3,120,153)**
Flare	(2,847,409)
Landfill Gas-to-Energy	(272,744)
Oxidation at MSW Landfills	**26,628**
Oxidation at Industrial Landfills	**23,705**
Total CH_4 Emissions	**452,999**

CO_2, N_2O, and CH_4 Emissions from Waste Combustion (MTCO$_2$E)

Gas/Waste Product	2005
CO_2	**139,562**
Plastics	96,456
Synthetic Rubber in MSW	14,407
Synthetic Fibers	28,699
N_2O	**3,163**
CH_4	**86**
Total CO_2, N_2O, CH_4 Emissions	**142,811**

Total Emissions from Landfills and Waste Combustion (MMTCE)

	2005
CH_4	0.124
CO_2	0.038
N_2O	0.001
Total	**0.162**

CH_4 Emissions from Landfills (MTCE)

	2005
Potential CH_4	**988,223**

(table continued)

MSW Generation	923,573
Industrial Generation	64,650
CH_4 Avoided	**(850,951)**
Flare	(776,566)
Landfill Gas-to-Energy	(74,385)
Oxidation at MSW Landfills	**7,262**
Oxidation at Industrial Landfills	**6,465**
Total CH_4 Emissions	**123,545**

CO_2 and N_2O Emissions from Waste Combustion (MTCE)

Gas/Waste Product	2005
CO_2	**38,062**
Plastics	26,306
Synthetic Rubber in MSW	3,929
Synthetic Fibers	7,827
N_2O	**863**
CH_4	**23**
Total CO_2, N_2O, CH_4 Emissions	**38,949**

Table 21: Summary of N_2O and CH_4 Emissions from Stationary Combustion for Louisiana (SIT)

MMTCO$_2$E	2005
Residential	0.017
N_2O	0.004
CH_4	0.014
Commercial	0.009
N_2O	0.003
CH_4	0.006
Industrial	0.501
N_2O	0.347
CH_4	0.155
Electric Power	0.146
N_2O	0.133
CH_4	0.014
TOTAL	**0.674**

Table 22: Summary of Wastewater Emissions for Louisiana (SIT)

Emissions ($MMTCO_2E$)	2005
Municipal CH_4	0.30
Municipal N_2O	0.13
Industrial CH_4	0.00
Fruits & Vegetables	-
Red Meat	0.00
Poultry	-
Pulp & Paper	-
Total Emissions	**0.43**

VITA

Quang Tran was born and raised in New Orleans, Louisiana, in 1982. After graduating from McMain Magnet Secondary School in 2000, he attended Louisiana State University (LSU). There he found interest in the geographic studies and graduated in 2006 with a Bachelor of Science degree in geography. Upon graduation, he was given an opportunity to return to the New Orleans area to work for the Engineering Department of Jefferson Parish as a Geographic Information Systems (GIS) analyst. Quang continued to work in the same field at the City-Parish Planning Commission for the City of Baton Rouge. While working as a full-time employee, he was given permission to pursue graduate studies at LSU in 2009 in the environmental sciences master's program. By the end of 2011, he will graduate with a Master of Science degree, and will continue to apply his educational experiences professionally in attempts to make Louisiana a more sustainable and healthier place to live.